THE COMPASS.

A MONTHLY JOURNAL

FOR ENGINEERS, SURVEYORS, ARCHITECTS, DRAUGHTSMEN, AND STUDENTS.

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INDEX.

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

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LIGHT: ITS REFLECTION AND REFRACTION.

RAYS OF LIGHT proceed in all directions in straight lines from every object around us, whether such objects be in themselves luminous, as the sun, stars, etc., or only illuminated by borrowed light, such as a tower, pole or other landmark.

A number of such rays form, when united, a collection of straight lines, which may be either cylindrical or conical; such a collection of rays is termed a *pencil* of light, and the central line or ray of the cylinder or cone is called the *axis* of the pencil.

Rays of light in their passage may be arrested or obstructed by reason of their falling upon an opaque substance which diverts a portion of them from their original course and absorbs the remainder in itself; or they may be intercepted by a transparent substance such as glass or water, called a *medium*, through which a portion of them may pass. These two familiar cases, known as the *reflection* and *refraction* of light, are governed by fixed laws, a few of which we propose to examine, in so far as they govern the construction and use of instruments used in Surveying and other Engineering works.

When rays of light fall upon an opaque substance, it is found that they are more or less absorbed, and more or less remitted or reflected back again to the medium from which they proceeded, the degree of this absorption and reflection being dependent upon the nature of the body and of its reflecting surface. Thus, very highly polished surfaces reflect more light than dull ones, and glass coated with quicksilver, and certain metals are more suitable substances for the construction of reflectors and mirrors than any others.

The general laws which govern the reflection of light may be briefly stated thus:—

If a ray of light falls upon a reflecting plane surface, the angle thus formed by it with this surface will be the same as that formed by the reflected ray; thus, let A B be a ray of light falling upon the reflecting plane surface R S at B, and let B C be the reflected ray, then the angle A B R is equal to the angle C B S, also if D B be perpendicular to R S, the angle A B D, called the angle of *incidence*, will be equal to the angle of *reflection* C B D. The plane passing through the *incident ray* A B and the *reflected ray* B C is called the plane of incidence or the plane of reflection.

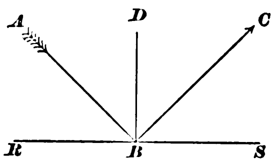


Fig. 1.

When parallel rays of light, forming a cylindrical pencil, fall upon a reflecting plane surface or mirror, they will be severally parallel after reflection as before, so that the angles of incidence and reflection of each individual ray will be all equal.

When diverging or converging rays of light, forming a conical pencil, fall upon a reflecting plane surface or mirror, they will continue to have after reflection the same degree of divergency or convergency as before, and the angles of incidence and reflection of each separate and distinct ray will be equal; thus in the figure, rays of light proceed from A to B, B^1, and B^{11}, and are severally reflected to C, C^1 and C^{11}. The angles of incidence A B D, A B^1 D^1 and A B^{11} D^{11} are therefore equal to the angles of reflection C B D, C^1 B^1 D^1 and C^{11} B^{11} D^{11}, and the degree of divergence of the separate rays from the mirror R S towards C, C^1 and C^{11} is the same as from the point A, whence they issue, to the

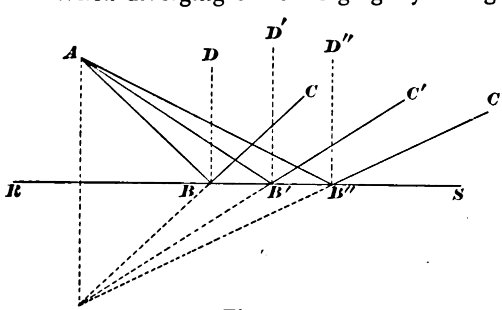


Fig. 2.

surface of the mirror. The converse in the case of converging rays also holds good.

The application of these laws is exemplified in that class of useful auxiliaries used with the Sextant for observing altitudes, namely the *Artificial Horizon*, of which we illustrate two different kinds.

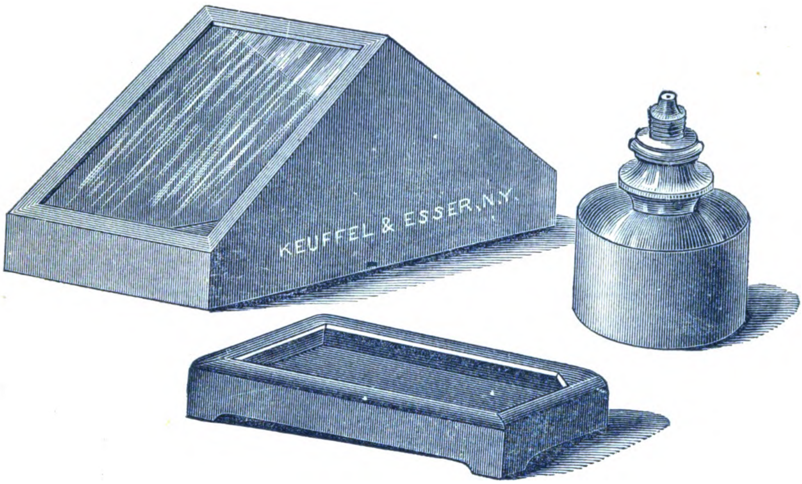


Fig. 3.

Figure 3 represents a Mercurial Horizon and consists of an iron trough into which the mercury is poured, its surface, when at rest, forming a perfectly horizontal plane mirror of the highest order. A glazed metal covering is provided to protect the surface of the mercury from currents of air, whilst an iron bottle to contain the mercury when not in use, completes the outfit. The bottle is made with a screw stopper and funnel-shaped cap to facilitate the pouring of the mercury from the tray when replacing it in the bottle.

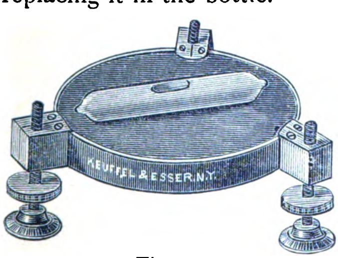


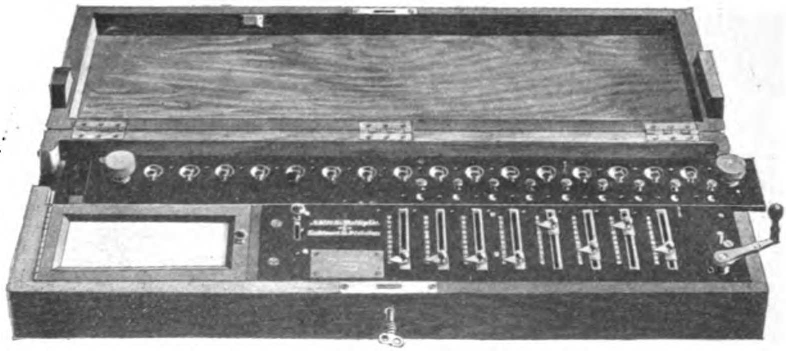
Fig. 4.

Fig. 4 represents a Reflecting Horizon, formed by a black plate-glass plane mounted in a brass frame, $3\frac{5}{8}$ inches diameter, provided with three leveling screws and a spirit level, to enable the mirror to be adjusted to a perfectly horizontal position.

The use of these instruments, which depends upon the broad principles laid down, will be explained in a future article descriptive of the Sextant.

(*To be continued*)

THE RECKONING MACHINE.



WE DESCRIBED in the last volume of THE COMPASS several speedy calculating devices based on mathematical principles. The machine of which we give an illustration above may be said to be a Mechanical Calculator, as the results are obtained by means of certain mechanical combinations.

THE RECKONING MACHINE will perform with rapidity and unfailing accuracy calculations of every kind from simple addition to the extraction of square roots, and that without mental strain when the method of operating it has been fully mastered. The art of using this valuable instrument may be easily acquired in a few days, after which a couple of weeks' practice will enable any man of ordinary capacity to become fully competent in the use of this wonderful invention for mechanical calculation, provided he strictly follows the instructions furnished with each machine.

The Reckoning Machine is naturally an instrument of delicate structure, and owing to the nature of the work for which it is intended, is not made for rough treatment or undue knocking about in unskillful hands. It is, however, most solidly constructed and carefully finished, and will, with the exercise of ordinary care, last years without requiring any other attention than that of oiling the shaft bearings and some other parts of the internal mechanism.

THE RECKONING MACHINE is composed externally of two main parts:—

The Key-plate, or front part, is fixed in the mahogany case, and contains the interior shifting mechanism, which it covers.

The Figure-slide, or back part, which is movable to the right and back again, and also up and down upon its axle-rod.

These two parts form the external operating surface, and present all

the figures and appliances by means of which the different kinds of calculations are effected.

The *Key-plate* is fixed and to its right, as shown in the figure, is a handle which turns in one direction only, as the hands of a watch, thereby setting the whole mechanism in motion. A small arrow to the left of the handle points to one of the minor figure holes in the slide, in which the successive turns of the handle are recorded. To the left of the handle are found a series of grooves (6, 8 or 10 according to the size of the instrument) marked from 0 to 9 upwards on their left sides. An index slides up and down each groove and can, by means of a small button, be set opposite any of the figures on the side of the grooves. Further to the left of these *figure grooves* is a *steering-knob*, which can be moved upwards if the sum is to be in Addition or Multiplication, and downwards if a calculation in Subtraction or Division is to be effected, as indicated on the key-plate.

The *Figure-slide* presents two rows of figure holes, sunk into the slide, beneath which revolve discs, bearing the numbers 0 to 9; the lower row serves to indicate the number of turns given to the operating handle, thus affording a continual check upon, and test of, the successive products which appear in the upper row of figure holes. The two large ebony buttons at either end of the slide serve to turn all the discs to zero, and thus bring the instrument to its normal position, ready for operating. A small nob, arranged either above or below the holes, allows any separate disc to be turned either to the right or to the left, if it be required to change the figure. These two operations must however only be performed after raising the figure-slide upon its axle-rod, so as to sever all connection between the mechanism beneath the figure-slide and that beneath the key-plate.

To operate the machine, for Addition, for example :—See first that the steering-nob points to the word *Addition*, and that the instrument is in its normal position, with all the discs at zero, and the figure-slide pushed to the left as far as it will go. Then set the indices to the first horizontal row of figures, as 47325, beginning with the units 5 on the right, then the tens, and so on, and turn the handle round once, when the figures 47325 will appear in the top row of holes of the slide. Now set the indices to the next row of figures, as 65432, and turn the handle round once more, when 112757, the sum of these two numbers, will appear in the top row of holes. In this way any number of sums may be added together by setting down each in succession in the key-plate, and turning the handle round once after each setting, then reading the sum total in the top row.

Multiplication and subtraction are performed as easily, the operations for dividing and extracting the square root being a little more complicated, but easily learnt.

To operate the machine for Multiplication :—Set the steering nob to

Multiplication and see that the instrument is in its normal position, with all the discs at zero and the figure-slide pushed to the extreme left. Then set the indices to the larger of the two factors, (say 8765 to be multiplied by 4321) beginning with the units 5 on the right, then the tens, hundreds and thousands. Now turn the handle round once, when the figures 8765 will appear in the top row of holes in the slide. Raise the slide on its axle-rod, and slide it towards the right until the second minor figure-hole comes opposite the arrow to the left of the handle, and place it again in its horizontal position. Now turn the handle round twice, when the figures 184065 will appear in the top row of holes in the slide, which is equivalent to

$$\begin{array}{rcrcr}
8765 & \times & 1 & = & 8765 \\
8765 & \times & 20 & = & 175300 \\
\hline
8765 & \times & 21 & = & 184065
\end{array}$$

Raise the slide again and slide it on its axle-rod one more place to the right, and turn the handle round three times, answering to the hundreds of the multiplier, when the figures 2813565 will appear in the top row of holes in the slide, thus obtained

$$\begin{array}{rcrcr}
8765 & \times & 1 & = & 8765 \\
8765 & \times & 20 & = & 175300 \\
8765 & \times & 300 & = & 2629500 \\
\hline
 & \times & & & \\
8765 & & 321 & & 2813565
\end{array}$$

Once more push the slide another place to the right, and turn the handle round 4 times, corresponding to the thousands of the multiplier, when the figures 37873565 will appear in the top row of holes in the slide, thus obtained

$$\begin{array}{rcrcr}
8765 & \times & 1 & = & 8765 \\
8765 & \times & 20 & = & 175300 \\
8765 & \times & 300 & = & 2629500 \\
8765 & \times & 4000 & = & 35060000 \\
\hline
8765 & \times & 4321 & = & 37873565
\end{array}$$

In the minor holes of the slide will then be found the figures 4321, showing that the handle has in each case been turned round the correct number of times.

The handle should be turned round at an even steady rate of 3 or 4 turns per second, and should never be left in any position other than that indicated by a pin projecting above the key-plate, intended to support it when at rest. It will be seen that with the above rate of speed the mul-

tiplication of two factors, each composed of several figures, can be effected in a few moments.

The small white space shown on the left of the instrument is the opaque glass cover of an empty space which serves as a receptacle for oil, polishing leather, decimal counters, etc., and can be used as a slate for noting figures upon.

The Reckoning Machine will be found very advantageous where numerous products have to be obtained, one of the factors always remaining the same, this constant factor being set by the indices, and the products rolled off almost as quickly as the other factor could be written down.

The Reckoning Machine is made in three sizes, namely

Key-plate with 6 grooves, and Figure-slide with 12 holes in the upper row,
" " 8 " " " 16 " " "
" " 10 " " " 20 " " "

so that products in multiplication may be obtained with two factors each of 6 to 10 figures, and that with absolute certainty of the results being accurate. We have ourselves had frequent occasion to use this machine and can very strongly recommend it.

ON the 19th July, Messrs. Keuffel & Esser Co., the publishers of THE COMPASS, celebrated the 25th anniversary of the founding of their business. The ceremonies of the day were initiated at 11 o'clock, by the presentation to Mr. Keuffel and Mr. Esser of a handsome framed silver wreath, with suitable inscription, from the 46 employees of the New York House. The Fulton Street and Ann Street foundation stones of the large and commodious new building, now in course of erection (to replace the old one, become much too small for the increasing necessities of their growing business), were then laid by the founders of the firm, after which several toasts to the members of the firm and their *personnel*, the architect and contractors were heartily drunk. Rendez-vous was then given to all those assembled to meet at 2 o'clock at Berg's Oriental Park, Jersey City Heights, whither some 200 of the employees of the firm's factory at Hoboken, with their wives and children were also directing their steps. Music, dancing, games for children and other attractions were abundantly provided, while the wants of exhausted nature were by no means overlooked. At 8 o'clock a substantial repast was served, during which several speeches were made and the employees of the factory presented Mr. Keuffel and Mr. Esser with a beautiful and suitably engraved Loving Cup. Dancing was then resumed, and an agreeable evening spent, the "Home, Sweet Home" march being postponed by one and all until as late an hour as possible.

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

THE VALUE OF "PI."

A LETTER SIGNED T. R. W. appeared in a recent number of the New York *Tribune*, bearing the superscription *The Circle cannot be Squared*, (*sic*) in which the writer says :—

> "This is one of the seven polemic problems whose solutions constituted sacred knowledge, not to be attained until the human mind had reached a high plane of intellectual development.
>
> Many attempts have been made in every age to solve these problems and with some success. There is said to be a record of the quadrature of the circle in Egypt 500 years before the Exodus of the Jews. It is also claimed that the problem was solved by Hippocrates, 500 B. C.
>
> The oldest mathematical book in the world, the "Papyrus Rhind" in the British Museum, was written by Ahmes, an Egyptian scribe of King Raaus, about 2000 B. C. This, as translated by Eisenlohr, contains a rule for making a square equal to a given circle. This

rule says that the diameter of the circle shortened by one-ninth of itself gives a side of the required square. But this is not exact and therefore of no value.

Without doubt this problem and perhaps others of the seven polemic problems were solved and the solutions with much other Egyptian learning, lost in the destruction of the Alexandrian Library.

Pythagoras was probably the first to solve one of the problems. He doubled the square, and as a result of that discovery we have the 47th Prop. of Euclid.

One record states that a pupil of Aristotle named Sextus, was commissioned to convey the secret of squaring the circle to Archimedes, who at that time was the leading mathematician in applied geometry.

This secret consisted in the knowledge of a certain line found in every circle. This line was called the "Nicomedian Line" and is mentioned in the categories of Aristotle's Organon. During more than 2000 years this mystic line has eluded the search of a host of mathematicians. The most remarkable fact connected with its rediscovery is the extreme simplicity of its construction, which makes one wonder that it was not recognized earlier.

Draw a diameter in any given circle and a radius perpendicular to it. Through the middle point of this radius draw a chord from one extremity of the diameter. This chord is the side of a square equal in area to the plane of the given circle.

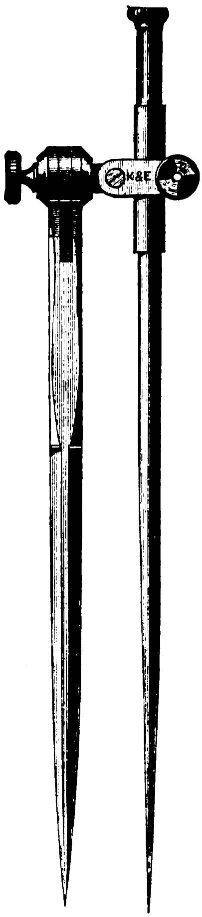
Making this line a standard measure for all geometric computations, it becomes a solving factor for all the polemic problems."

Assuming now, the diameter of a circle to be 4, we then have the chord $= \frac{8}{\sqrt{5}}$, consequently the area of the circle $= \left(\frac{8}{\sqrt{5}}\right)^2 = 12.8$.

Now the area of a circle $= \frac{\text{diam}^2 \times \pi}{4}$, whence $\pi = \frac{\text{Area} \times 4}{\text{diam}^2}$ $= \frac{12.8 \times 4}{16} = 3.2$

If only correct, how much simpler this value would be than the cumbersome old fashioned one of 3.14159 . . . which however has stood the test of centuries, and will continue to do so in spite of the vauntings of certain professors, (*sic*) T. R. W. and others.

THREE LEGGED DIVIDERS.



THE FIGURE HERE shown represents an instrument which will be found of great use in the draughting room, both for copying drawings and for plotting angles. The long round leg slides in a socket hinged to the joint and can be adjusted for length so as to enable larger measurements to be taken and angles to be set off with greater accuracy.

For copying drawings, the three legs of the dividers must be made to coincide with any three points of the original; two of the legs must then be set upon two already determined points of the copy, when the third leg of the dividers will indicate at once the position of the unknown point on the copy.

For laying off angles, take a paper protractor, about 8 or 10 inches diameter, and set the adjustable leg exactly in the centre, having previously pushed it out to its fullest length. With the points of the two other legs, take off on the circumference of the protractor the desired angle, which can be done with great nicety. Transfer then the long leg of the dividers to the apex of the angle on the drawing, and lay off with the other legs two points to indicate the direction of the sides of the angle; the required angle can then be easily and quickly plotted.

Other uses of this handy instrument will readily suggest themselves. The quality is that so well known by the term PARAGON, while the finish and easy motion of the joints is all that could be desired. The illustration is two-thirds size.

SUBTERRANEAN TEMPERATURE.

CAREFUL OBSERVATIONS have been recently made in Germany in a deep bore-hole to ascertain the rate of increase of temperature compared with the corresponding increase of depth below the general level of the surface of the earth. They showed that the increase in temperature is both regular and constant, it being 45.3° R. (138.8° Fahr.) at a depth of 5628 feet, the increase being at the rate of 1° R. for every 46.09 metres of depth, (= 1° Fahr. for each 67.2 feet).

From the data supplied by Mr. M. Hasslacher, who was in charge of the work, Mr. Charles Zundel, in a paper recently read before the Société Industrielle de Mulhouse, gave the following formula for calculating the temperature in degrees Réaumur, at any given depth:

$$R = 8.3 + \frac{P - 6}{46.09}$$

in which P represents the depth in Metres.

From the above we deduce the following equivalent formula for degrees Fahrenheit, at any given depth:

$$F = 50.68 + \frac{D - 19.68}{67.2}$$

in which $D =$ depth in Feet.

ENGINEERING AND SURVEYING INSTRUMENTS.

The Level.

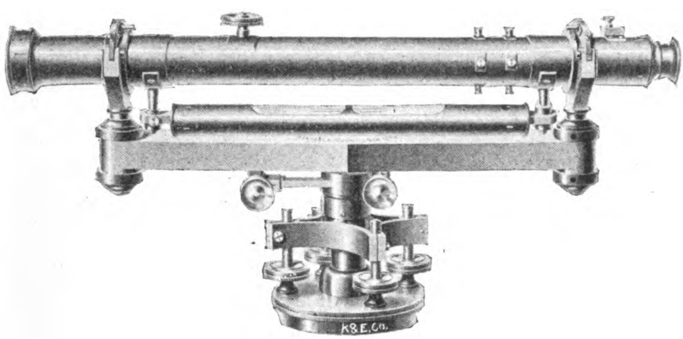


Fig. 1.

Leveling is one of the most important of the Surveyor's or Engineer's operations. Precise leveling is the art of tracing an artificial horizontal line which shall, in every direction, be exactly or as near as possible, at right angles to that earth's radius upon which the operator is located.

Various kinds of instruments are employed for ascertaining horizontal lines, but the one most generally used for accurate work is that called the Engineer's Y Level, shown in Fig. 1.

It consists of a telescope, to which is attached a long spirit level, reposing in wyes or vertical supports connected with a horizontal bar, which is firmly secured to a central or vertical axis upon which the whole may

revolve. It will be evident from the above definition of leveling, that the vertical axis should coincide absolutely with the earth's radius by which it is traversed, and that the horizontal bar, level and line of sight of the telescope should be perpectly parallel to one another in all positions and also absolutely at right angles to the vertical axis.

This instrument is in its main parts similar to others of the same type, although, as in the case of the Transit, described in the last volume of THE COMPASS, many important improvements have been introduced.

The centre is of gun-metal and sufficiently long to give stability and allow of easy and steady rotation even after long use; the ordinary leveling plate is replaced, by four arms, shown in Fig. 2, of light but strong construction, joined to the outer sleeve at *r*, *r*, so that in case of a blow or straining of the leveling screws, this distribution of the points of connection with the sleeve would prevent it from being distorted and protect the centre from injury. This arrangement also gives more room for manipulating the leveling, clamp and tangent screws. The two latter are made to revolve with the telescope so that they always remain in the same relative position and are always equally accessible. The tangent screw is of very hard German silver and is provided with an opposing or compensating spring to prevent lost motion.

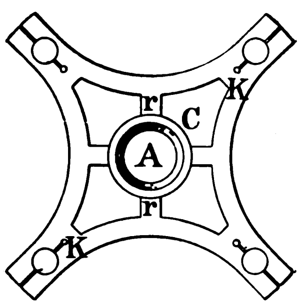


Fig. 2.

The bar, which is of gun-metal, is flat and shaped so as to combine the greatest strength with the least weight, the main part of the weight bearing directly upon the centre. The underside of the bar is ribbed to avoid unnecessary weight.

The wyes in which the telescope rests are substantial and firmly fixed to the horizontal bar, being secured by nuts which are adjusted by a steel pin; one of the wyes is capable of a slight vertical movement by means of double nuts, to insure the horizontality of the wyes when the bubble is in the centre of the tube.

The telescope is locked in the wyes by a patented arrangement dispensing with the usual pin bolts which are apt to be lost. One end of each of the clips is hookshaped, as shown in Fig 3, and engages with a pin in the wye, half of which is cut away, thus forming a cam. A half-turn of this cam either way, effected by a small lever, locks or unlocks the clip and holds the telescope secure. A pin in the clips of the wyes, acting against a stop attached to the telescope, enables the latter to be at once so placed in the wye supports that the cross hairs may be vertical and horizontal.

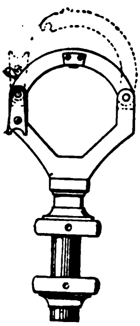


Fig. 3.

The telescopes vary from 15 to 22 inches in length and are similar in construction to those described in connection with the Transit. The object-glass is brought into focus by means of a patent rack and pinion, with anti-friction movement which can neither bind nor interfere with free motion, thus enabling the telescope to be both easily and accurately focused. The eye-piece is adjusted by a patent lever which is a simple and ingenious improvement, both easy and positive in action, enabling the focusing to be effected with the greatest nicety. The milled heads for moving the objective and ocular are placed on the top of the telescope, so that they may be conveniently accessible to either hand.

The spirit level attached to the telescope is long and sensitive, the bubble tube being finely graduated and carefully tested to ascertain the angle covered by the movement of the bubble through one single division, this value being marked on the end of the tube. The tube is adjustable both vertically and horizontally, so that its axis may be brought into coincidence with the line of collimation of the telescope.

It will be seen from these particulars that every facility is provided for accurately adjusting the various parts of the instrument, so as to insure good work being performed with it.

(To be continued.)

ANALYSIS AND TESTS OF DRAWING PAPER.

The multiplicity of materials used by paper manufacturers has rendered the testing and analysis of this product a difficult operation, and one which necessitates the use of really scientific methods.

The following is, according to the *Revue de chimie industrielle*, the method by which these tests are carried out at Charlottenburg. The operations relate to the following points:—

a. Tenacity and elasticity.
b. Resistance to rubbing.
c. Thickness.
d. Nature of the size employed.
e. Ashes.
f. Nature of the materials composing the stock.
g. Presence of chlorine or free acid.

The analysis includes mechanical processes, chemical essays and especially microscopic examinations.

To determine the tenacity, a certain number of strips, taken in different senses, are tried on a special machine, called the Gartyg-Reisch: the mean of the results is taken, and the tenacity is expressed in terms of the length of the strips essayed, whereat they break: this figure is easily deduced when the weight of the paper and the coefficient of tension are known.

The Gartyg-Reisch machine gives also the degree of elasticity of the paper.

For the resistance to rubbing, a sample is simply rubbed between the hands during a given time: the number of operations necessary to obtain complete disaggregation is proportional to the quality of the paper.

The thickness is determined very exactly by means of an instrument provided with a micrometer screw.

The nature of the size is determined by means of chemical reagents: a sample of the paper is boiled in water and a solution of tannin is poured into the decoction; if gelatine (animal glue) be present, a precipitate shows itself, or the liquid becomes at least turbid. To liberate vegetable glue, a decoction is made of the paper in alcohol; when this decoction is poured into cold water, the resin is precipitated.

The amount of the size in the paper is estimated by the following ingenious method; several lines are traced on one side of the paper with an aqueous solution of perchloride of iron, and the paper is then laid on a solution of tannin with the unwritten side downwards; the time which elapses between the placing of the paper in the bath and the blackening of the lines is proportional to the amount of size.

Commercial cellulose does not leave one per cent. of ashes; if the paper leaves a greater proportion, it proves that mineral substances have been employed, and the percentage of them is easily determined.

The presence of chlorine is easily detected by means of starch, saturated with iodide of potassium; this latter then takes a bluish hue.

The detection of free acids is a very delicate operation, and is preferably performed by the Gertzberg process, by means of a sensitive red.

In good papers, however, it is rare that traces of either chlorine or free acids are discovered.

The microscopical tests are often very useful; a small piece of the paper is placed on the stage of the instrument, and a drop of a solution of iodine poured upon it; if the paper is made from wood pulp, the fibres will turn yellow; if flax, hemp or cotton alone form the stock of the paper, the coloration of the fibres will be brownish yellow, and if the paper be made of pure cellulose, the iodine will in no way affect the color of the fibres.

It is better, for the microscopical examination, after having damped the paper with the iodine solution, to boil it in a porcelain capsule with a

few drops of alcaline solution; if the paper is sized, the solution will become after 2 or 3 minutes of a yellowish tint. After a quarter of an hour's boiling, the paper pulp is washed in water, then held in fresh water to be examined with the microscope.

The appearance of the different vegetable fibres is not the same in the pulp of the paper that it is at the beginning of the process of manufacture; the determining of the materials composing the stock is therefore difficult and can only be done by an expert. The *Bulletin de la Société d'encouragement pour l'industrie nationale* published some time ago a series of drawings which singularly facilitate the determination of the fibres.

It is well known that the average quality of the paper made in Germany has sensibly improved of late years, and there is no reason to doubt that this result is in a great measure due to the influence of these scientific analyses and tests.—*Revue Scientifique.*

THE SHADING OF DRAWINGS.

THE LINE SHADING OF DRAWINGS is an important part of the draughtsman's work, if general and artistic effects are taken into consideration. The Section-Liner described in our last number will be found to be a very useful instrument for doing this neatly, accurately and with dispatch. A sample card of shadings can be easily made with the following simple Settings, from which any degree of shading as desired may be afterwards selected, and the arm at once set to produce the same :—

Setting with one tooth	10°	20°	30°	40°	50°	60°	70°	80°	90°
Lines per in.	138	$70\frac{1}{6}$	48	$37\frac{1}{3}$	$31\frac{1}{3}$	$27\frac{2}{3}$	$25\frac{1}{2}$	$24\frac{1}{3}$	24

or, in some cases, the following may be found more suitable :—

Lines per in.	10	20	30	40	50	60	70	80	90	100
Setting	53.1°	36.9°	53.1°	36.9°	28.7°	23.5°	20.1°	17.3°	15.5°	13.9°
No. of teeth	3	2	1	1	1	1	1	1	1	1

The great advantage of this method is that any particular degree of shading can be easily and accurately reproduced, so that absolute uniformity may be secured, although the drawings may have been executed at very different times.

It is especially desirable that drawings intended to be copied by the *Blue Print* or *Nigrosine* Process should be shaded with care, as any slovenliness becomes most apparent. For such, therefore, Both's Section-Liner is both the best and the simplest.

NEW BOOKS.

THE MICHIGAN ENGINEERS' ANNUAL for 1892, gives a detailed account of the Proceedings of the Michigan Engineering Society during the past year with a full report of its doings at the annual convention held at Grand Rapids on January 19, 20 and 21, as well as the papers read and discussions proceeding therefrom. The work is well printed in clear type on good paper, and is worthy of a place in the Engineer's and Surveyor's library by reason of the interest attaching to the many subjects brought under review. We are pleased to note that this society under the presidency of Professor J. B. Davis of Ann Arbor, ably seconded by Mr. F. Hodgman, A.S.C.E., the well-known author of a *Manual of Land Surveying*, as Secretary, is flourishing and reaching forward to higher attainments.

INDUSTRIAL AND MANUAL TRAINING IN PUBLIC SCHOOLS, being Part II of a Special Report on EDUCATION IN THE INDUSTRIAL AND FINE ARTS IN THE UNITED STATES, prepared and compiled by Isaac Edward Clarke, A.M., in compliance with a resolution of the U. S. Senate. This volume forms a fitting companion to Part I on DRAWING IN PUBLIC SCHOOLS, and the two contain an exhaustive review of "certain educational theories and experiments that are just at present occupying the attention of educators all over the civilized world."

It has now long been conceded that in these days of progress, special industrial teaching is of the highest importance, not only from a commercial standpoint, but also from a moral one. To become preeminent in arts, sciences, manufactures and industries is not the work of a day, nor is such a high honor attained by intuition, but by close searching after, feeling for and reaching towards the truths which lie at the very foundation of all science and art. That progress may be general and perpetual, it is necessary that the results of the searchings and probings with the consequent lessons learned, and the struggles and resulting victories won by the noble leaders of the past and of to-day, shall be not only simply handed down for the benefit of their immediate successors, but shall be so inculcated in our public and industrial schools and colleges, that our students may be fitted to take a higher stand when they set out on the serious and active march of life, and so by devoting their whole energies to the race before them, may be enabled to attain greater pre-eminence and achieve greater victories than their predecessors.

This most interesting volume tells us in an able and agreeable manner what has been done, and what is being done, in this and other countries to accomplish these purposes, and its perusal will well repay those in any way interested in the present "Industrial Education Movement."

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. SEPTEMBER, 1, 1892. No. 2.

UNIVERSAL PROPORTIONAL DIVIDERS.

WE HAVE STATED in previous numbers of THE COMPASS that we considered it would be a great advantage if Proportional Dividers were graduated from point to point and divided into a convenient number of equal parts, so that the slider could be set to give any desired ratio between the opening of the points of the two ends. Such an instrument is now offered to the public by the Publishers of THE COMPASS, and we proceed to describe the same and to enumerate a few of the uses to which it may be put.

These Dividers, called UNIVERSAL PROPORTIONAL DIVIDERS, and for which a patent has been applied for, are 10 inches long from point to point, and are graduated throughout half their length to a scale of 200 equal parts, reading to tenths by means of a vernier which replaces the ordinary slider. The settings are made with a rack and pinion which provides an easy and accurate mode of adjustment, and the fine steel points are movable, being held firmly by screws, so that they can be set to their original length or replaced in case of breakage. They can also be had with the usual solid leg.

Figure 1 shows this instrument, with the exception of the scale of equal parts which takes the place of the graduations shown, and the vernier which replaces the ordinary slider with a single setting line.

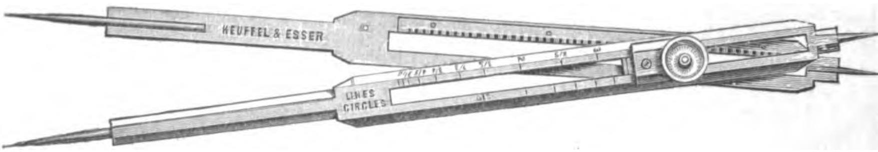


Fig. 1.

We have already shown that the graduating of Proportional Dividers depends upon the Proposition that *when two sides of a triangle are proportional to the two sides of another triangle, each to each, and their included angles are equal, then the third side of the one bears the same proportion to the third side of the other.*

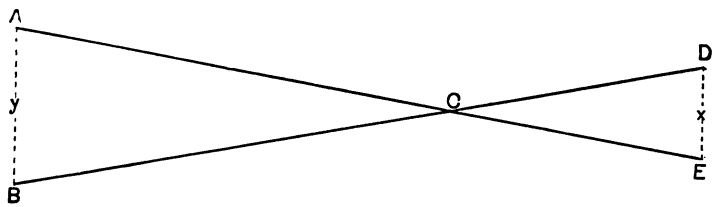


Fig. 2.

If therefore, in Fig. 2, the length of AC is to the length ot CD as 5 is to 3, then will the opening y be to the opening x, as 5 is to 3. To find the position or setting of C, corresponding to the pivot of the Proportional Dividers, we have the formula

$$S = \frac{L \times x}{x + y}$$

where $L =$ the total length of the Dividers
$x =$ the lesser term of the ratio, corresponding to CD,
$y =$ the greater term of the ratio, corresponding to AC,
and $S =$ the distance of the pivot C, measured from the end D.

In the instrument we are describing, the *whole* length AE is supposed to be divided into 200 equal parts, reading with a vernier on the slider to 2000 parts. If therefore we wish to set the Dividers to give the proportion of 5 to 3, we have

$$S = \frac{2000 \times 3}{3 + 5} = 750$$

We therefore by means of the rack adjustment set the slider to 750, and have the opening x equal, by any scale of equal parts, to 3 and the open-

ing y equal to 5, seeing that 3 : 5 as 750 : 1250 and 750 + 1250 = 2000. Any other desired simple proportion may be obtained in the same manner.

Settings equivalent to the graduations of the Scale of Planes are obtained by means of the formula

$$S = \frac{2000 \times \sqrt{x}}{\sqrt{x} + \sqrt{y}}$$

and the Settings equivalent to the graduations of the Scale of Solids of the ordinary Proportional Dividers are obtained by the following formula

$$S = \frac{2000 \times \sqrt[3]{x}}{\sqrt[3]{x} + \sqrt[3]{y}}$$

A table however accompanies each instrument giving the Settings for more than 30 ratios each, for Lines, Planes and Solids, besides several miscellaneous proportions, which will often be found useful, and to some of which we will refer, as they can frequently be made to replace tables.

Setting 483 gives the ratio of the Diameter to the Circumference of a circle, (1 to 3.1416) and will be useful amongst other things for reducing circular motion to linear, and vice-versa. It may also be used with a scale of equal parts (say 30 to the inch) for finding diameters and circumferences.

Setting 939 gives at one end the Diameter of a Circle and at the other end the side of an Equal Square, based of course upon the usually accepted value of π. This is a practical method of solving the polemic problem of the *Quadrature of the Circle*, which we venture to believe will be found more useful than the one described by T. R. W. in our last issue.

Setting 893 gives the relative values of the Diameter of a sphere and the side of a Cube of equal contents, which will often be found of practical utility.

Setting 467 gives the ratio between Feet and Metres, by means of which dimensions may be taken from a drawing and converted from one measure to the other. Other settings give the ratio between Yards and Metres, also between Miles and Kilometres.

Many other settings for similar ratios may be as easily obtained by means of the simple formula given, and when calculated put into tabular form, thus considerably facilitating the graphic solution of practical problems in mechanics, etc.

We have also calculated a special table which gives at one end of the Dividers the radius of a circle and at the other end the chord corresponding to any given angle; thus with Setting 971 corresponding to an angle of 64°, if we open out the points of one end to take in a radius of a circle

measuring by any convenient scale 117 such parts, then we shall find by the opening of the other end that the chord of 64° to a radius of 117 will measure by the same scale 124 parts. We may naturally also take the chord 124 as being given, and find in a similar manner the radius. Practical uses of this table will suggest themselves to the Engineer and others.

From these few particulars, it will be seen that the UNIVERSAL PROPORTIONAL DIVIDERS are not only capable of doing anything that can be done with the ordinary Proportional Dividers, but that they may be applied to a great many other uses, as any required ratio may be set off with them. The setting of the vernier from a table of Settings is also just as easy as the setting of the slider when the instrument is merely graduated for each separate ratio. These instruments are of the very best or PARAGON make and may be fully relied upon for their accuracy.

LIGHT: ITS REFLECTION AND REFRACTION.

IF A RAY OF LIGHT, after being reflected from a plane mirror, falls in the same plane upon another plane mirror, the angle formed by the incident ray of the first mirror and the reflected ray of the second mirror, is equal to twice the angle formed by the surfaces of the mirrors themselves.

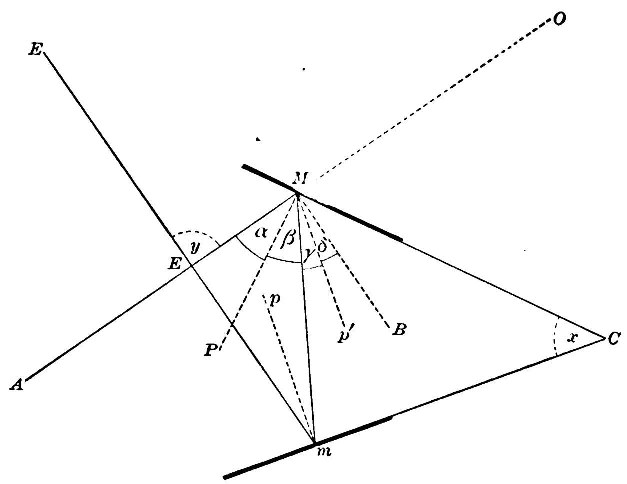


Fig. 1.

In Fig. 1 let M and m be two mirrors, both perpendicular to the same given plane, and let $E\ m$ be an incident ray of light proceeding from some object at E and falling upon the plane surface m from which it is reflected, becoming an incident ray and falling upon the mirror M, from

which it is finally reflected toward A. Now, according to the law just stated, the angle y formed by the intersection of the first incident ray $E\,m$ and the second reflected ray $M\,A$, is equal to twice the angle x formed by the plane surfaces of the mirrors M and m produced to C. That this is so, will be clear from the following demonstration.

Draw $M\,B$ parallel to $E\,m$,
$M\,P$ perpendicular to $M\,C$,
$m\,p$ perpendicular to $m\;C$,
and $M\,p^1$ parallel to $m\,p$, then

Angle $A\;M\,B = y =$ the difference of the first and last direction of the ray;

Angle $P\;M\;p^1$, formed by the perpendiculars to the two mirrors
$=$ Angle $M\;C\,m = x$,
$=$ Angle which the two mirrors make with each other.

Angle $m\;M\,B =$ Angle $E\;m\;M = \gamma + \delta = E\;m\,p + p\;m\;M$.

Now as the angles of incidence and reflection are always equal, the angles γ, δ, $E\;m\;p$ and $p\;m\;M$ are all equal to one another, and as α and β are also equal to each other, it is evident that

$$\alpha + \delta = \beta + \gamma$$

whence

$$\text{Angle } A\;M\,B = (\alpha + \delta) + (\beta + \gamma) = 2\;(\beta + \gamma)$$

that is

$$\text{Angle } A\;M\,B = \text{Angle } M\;C\,m \times 2.$$

This law of double reflection has been applied to the construction of several instruments which are of great use to the Engineer, Surveyor and Navigator, a few of which we shall notice.

The simplest one is that known as the Angle Mirror or Optical Square, of which three different kinds are shown herewith.

They all consist of a small metal box, to two of the inner walls of which are attached small mirrors, forming with each other a given known angle, generally 45 degrees. Immediately over the mirrors are two windows or open spaces, through which distant objects can be sighted. The instrument is held in the right hand by the handle in such manner that the observer can look straight through the window in the direction $A\;O$, Fig. 1, and also at the same time see other objects reflected in the mirror M from the mirror m. If the two mirrors are fixed at an angle of 45 degrees, then, as seen by Fig. 1, the angle formed by an object at O, seen from A through the window, and the rays of light proceeding from an object at E, seen in the mirror M by double reflection, immediately below the object O, but appearing to vertically coincide with it, is an angle of 90 degrees. In this way a perpendicular may be very easily set out from y upon the straight line $E\;m$, by turning the instrument round until a rod

at *E* is seen in the mirror *M.* Looking now over the mirror through the window, directions may be given for placing another rod at *C* so that it shall appear to be in a vertical line with the rod at *E* seen in the mirror. When using the instrument a plumb-bob should be attached to the handle and suspended over the point *y* over which a perpendicular is to be erected.

Fig. 2.

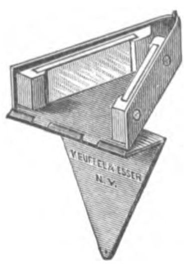


Fig. 3.

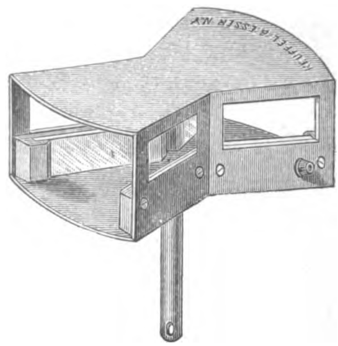


Fig. 4.

Figure 2 represents a very handy instrument for angles of 90 degrees, with plumb-bob screwing into the handle, which can be detached and placed in the frame of the instrument. The size of this Angle Mirror is $2\frac{1}{4}$x2x$1\frac{3}{4}$ inches.

Figure 3 is an Angle Mirror for angles of 90 degrees, and is very convenient for the pocket, as the handle is formed by the cover which folds under. Although there are no "windows," the distant object *O* can be seen just as easily over the mirror *M.*

Figure 4 is a larger instrument, one end being for angles of 90 degrees, and the other end for angles of 45 or 60 degrees as preferred.

It is usual to have the mirrors of these instruments adjustable by means of set screws, and it is advisable to test them before using them if accuracy is required. To do this, lay off a perpendicular to a given line, as described, then turn round towards the right about 90 degrees, but keeping the plumb-bob continually suspended over the same point, until the rod *O* is seen in the mirror *M,* then set another rod to coincide, when seen through the window *M,* with the rod *O.* Repeat this operation until the last window sight *ought* to fall upon *E,* then, if the rod *E* coincides with the image in the mirror of the previous rod, the two mir-

rors are placed exactly at an angle of 45 degrees with each other. If they do not agree, the difference represents four times the error, plus or minus, of the setting of the two mirrors, which must be adjusted accordingly. Care must also be taken that both mirrors are truly perpendicular to the same plane.

Another class of Angle Mirrors is constructed so that the angle of inclination of the two mirrors may be considerably varied, this inclination being determined by a graduated arc and an index hand, with or without a vernier attached to the mirror and revolving with it. This arc is sometimes figured according to the angular distance of the objects sighted, and sometimes in accordance with the angle of inclination of the mirrors.

With such an instrument offsets may be laid down at any angle up to about 150 degrees from a given base. Distances to inaccessible objects may also be approximately calculated, as follows:—Let B be the point of observation, equivalent to y in Fig. 1, and let it be required to find the distance $A\ B$. Set the instrument to 90°, (that is, angle of inclination of the mirrors, $x = 45°$) and erect a perpendicular $C\ B$ on $A\ B$. Now transfer the instrument to C and hold it so that a rod at B can be seen reflected in the mirror, then turn the index of the graduated arc until the point A is seen above through the window in coincidence with B. Read off the angle $B\ C\ A$ on the arc, and measure carefully $B\ C$. Then

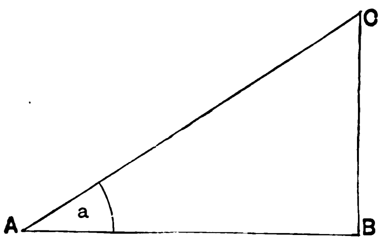


Fig. 5.

$$A\ B = B\ C \times \text{Tan}\ B\ C\ A.$$

Thus, let $B\ C = 50$ feet, and angle $B\ C\ A = 55°$, then

$$A\ B = 50 \times 1.428 = 71.4 \text{ feet.}$$

Another and simple method of making the computation is with the Slide Rule, as explained in Vol. I of THE COMPASS, page 75, thus

Scale A.	To $B\ C = 50$ feet	Find Side $A\ B = 71.4$ feet
Scale Sines	Set $a = 35°$	Over Angle 55°

One advantage of this method is that the length of the side $A\ C$ is also immediately found on scale A over 90 degrees.

We have seen a very handy Folding Angle Mirror, occupying but a space of 3x1x¾ inches, and measuring angles up to 130 degrees, which would often be found a very useful and handy companion, not only for the Surveyor and Civil Engineer but also for the Tourist, Traveller or Amateur.

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

ENGINEERING AND SURVEYING INSTRUMENTS.

THE LEVEL.

(Continued.)

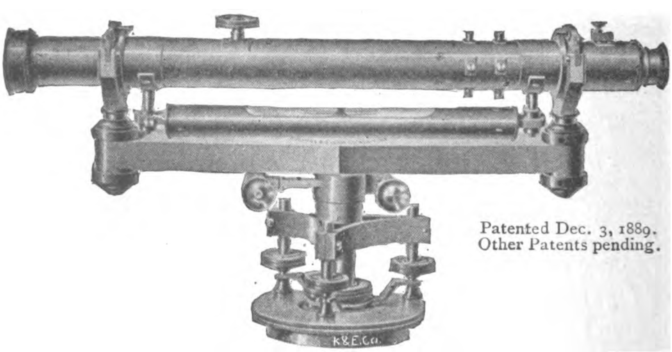

Fig. 1.

WHEN THE ENGINEER'S Y Level is required for *very accurate* work, it is often provided with three leveling screws, as shown in Fig. 1, and the telescope employed is also frequently an astronomical one, that is, with inverting eye-piece, which is composed of two lenses only, as this eye-piece has the great advantage of rendering the image more brilliant than the erecting one and consequently producing better definition besides being adapted to longer ranges, whilst also increasing the field of view. The inconvenience, experienced at the outset, of all objects being seen inverted, is overcome with a very little practice, after which the astronomical eye-piece will be found to be, as in Europe, generally preferred.

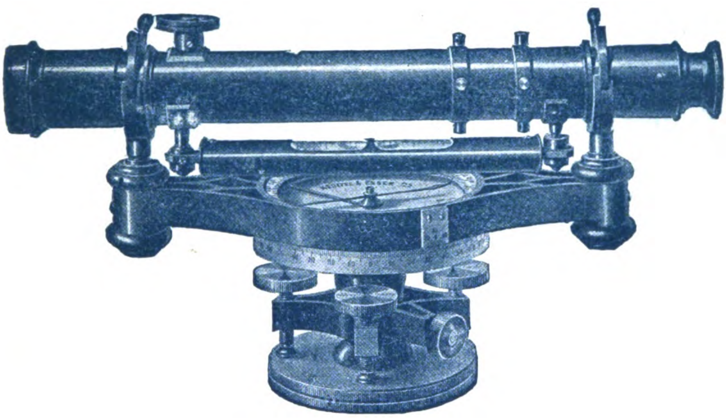

Fig. 2.

Figure 2 shows a smaller instrument, called an Architects' or Builders' Y Level, the telescope being 11 inches long, of fair magnifying power and good, clear definition. This Level is provided with a compass divided to degrees, and a horizontal circle, 3 inches diameter, attached to the outer centre, divided to degrees, figured in quadrants from 0° to 90° each way, and reading to 5 minutes with a vernier fixed to the level-bar, so that horizontal angles may be measured and bearings taken. In some cases the compass is dispensed with. The telescope is clamped in the wyes in the same manner as in the Engineer's Level, and when directed upon an object it can also be clamped to the vertical axis or spindle by the milled head shown in the figure between two of the leveling screws.

The level may be used either with a light tripod or with a trivet, shown in Figs. 3 and 4, which consists of a triangular metal plate, with three pointed feet for holding it securely upon a piece of stone or wood, as on the top of a wall or a rafter.

The Builder's Level is capable of being adjusted exactly in the same manner as the larger or Engineer's Level, that is, for the line of collimation,

the level bubble and the wyes, and when correctly adjusted may be relied upon for good work.

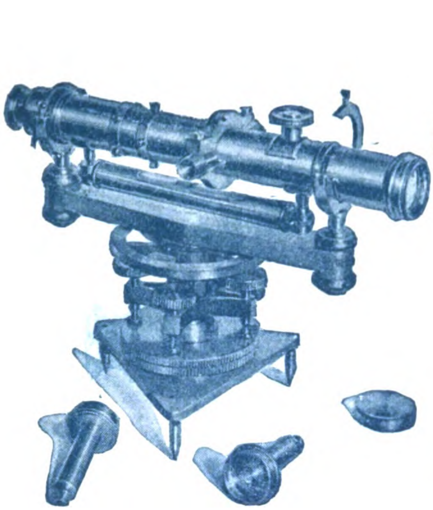

Fig. 3. (Arranged for Leveling.)

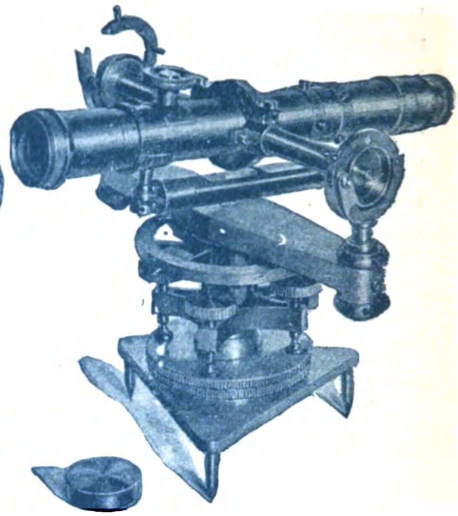

Fig. 4. (Arranged for Vertical Sighting.)

Another form of Builder's Level is shown in Figs. 3 and 4, which embodies a new and patented arrangement, by means of which the level may be made to combine certain of the qualities of a transit with its own special ones.

A substantial collar is attached to the body of the telescope at or near its centre of gravity, into which two trunnions can be firmly screwed exactly at right angles to the optical axis of the telescope; the outer end of each of the trunnions is provided with a cylindrical bearing, of the same diameter as the body of the telescope, the whole thus forming a solid axis as in the transit, upon which the telescope may be made to turn in altitude, if taken out of the wyes, turned half-round and replaced with the trunnion bearings resting in the wyes, as shown in Fig. 4, where they are locked in the usual manner.

With the telescope thus placed, and able to rotate on its axis, vertical lines may be determined, and horizontal angles, between two points not in the same plane, may be measured by means of the graduated circle, as is done with the Transit. If the telescope be turned half-round and over, then replaced in the wyes, with the level above instead of beneath the telescope, it can be rotated through an angle of elevation of 40° and depressed to the same extent. To facilitate this operation, the milled head for focusing the objective, is placed on the side of the telescope instead of on the top, as shown in the figures.

Builders and Architects will find the CONVERTIBLE LEVEL, as described, a very useful and convenient instrument, simple to handle and thoroughly efficient for the purposes for which it is particularly intended. When the instrument is used as an ordinary Level, the trunnions are placed in special receptacles in the box, so that the operator need be in no way encumbered with them.

(*To be continued.*)

THE PANTOGRAPH.

WE DESCRIBED IN a former number a Pantograph of improved construction, and gave a few particulars as to the method of using it with the manner of obtaining Settings for enlarging and reducing. We propose in the present article to explain the principles upon which the construction and use of this instrument depend.

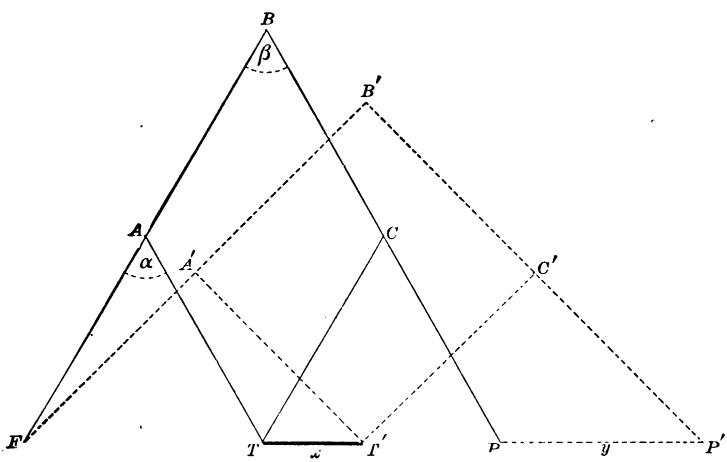

Fig. 1.

Let us suppose that in Fig. 1, $B\ F$ and $B\ P$ represent the long arms of a Pantograph for the *Erect* method for enlarging, and $A\ T$ and $C\ T$ the short arms, the Tracer being at T, the Pencil at P and the Fulcrum at F; and in like manner let $B^1\ F$ and $B^1\ P^1$ represent the long arms and $A^1\ T^1$ and $C^1\ T^1$ the short arms of the same instrument, but in another position, the tracer being moved from T to T^1 and the pencil from P to P^1, these distances indicating the proportion between the original drawing and the enlarged copy, which proportion we designate by the ratio x to y.

The Pantograph should be constructed so that $A\ B$, $B\ C$, $A\ T$ and $C\ T$ are all of equal length, forming an equal sided parallelogram; then, however large or small the angle β may be, the opposite sides $A\ B$ and $C\ T$, and $B\ C$ and $A\ T$ are always parallel, and the angle α is consequently always equal to the angle β.

Let $A\ F$ be made equal to $A\ B$ and $C\ P$ equal to $B\ C$, then by the theorem (Euclid VI, prop 6), that

> *If in two triangles two sides of the one are proportional to two sides of the other, and the included angles are equal, the two triangles themselves are similar,*

the triangle $F\ A\ T$ is similar to the triangle $F\ B\ P$ and the triangle $F\ A^1\ T^1$ is similar to the triangle $F\ B^1\ P^1$, and the three sides of the one are proportional to the three sides of the other, each to each, and the angles of the one are equal to the angles of the other, each to each that is

$$F\ A : F\ B :: A\ T : B\ P :: F\ T : F\ P$$

and

$$F\ A^1 : F\ B^1 :: A^1\ T^1 : B^1\ P^1 :: F\ T^1 : F\ P^1$$

Now as the sides $F\ A$, $F\ B$, $A\ T$ and $B\ P$ are equal to the sides $F\ A^1$, $F\ B^1$, $A^1\ T^1$ and $B^1\ P^1$ respectively, then

$$\left.\begin{matrix} F\ A : F\ B \\ A\ T : B\ P \end{matrix}\right\} :: F\ T : F\ P :: F\ T^1 : F\ P^1$$

and, by subtraction

$$\left.\begin{matrix} F\ A : F\ B \\ A\ T : B\ P \end{matrix}\right\} :: F\ T^1 - F\ T : F\ P^1 - F\ P$$

whence $$F\ A : F\ B :: T\ T^1 : P\ P^1$$

that is $$F\ A : F\ B :: x : y \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1.}$$

and $$A\ T : B\ P :: T\ T^1 : P\ P^1$$

that is $$A\ T : B\ P :: x : y \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 2.}$$

It is usual in the case of Pantographs for the Erect method to have $C\ P = B\ C$ and $F\ A = A\ B$, as shown in Fig. 1, where F represents the Fulcrum which is movable, T the Tracer which is also movable and P the Pencil which is fixed.

It is clear therefore, that as the length of the long arm $B\ P$ always remains the same, the positions of the fulcrum and tracer must be adjustable, and that they will depend upon the values assigned to x and y, that is the proportion intended to exist between the original drawing and the copy, and that the available length of $A\ F$ and $A\ T$ will depend upon the same proportion.

We can obtain at once from Eq. 2 the length of $A\ T$, the length of $B\ P$ being known, thus

$$A\,T : B\,P :: x : y$$

whence $$A\,T = \frac{B\,P \times x}{y} \ldots\ldots\ldots\ldots \text{Eq. 3.}$$

To ascertain the length of $A\,F$, the length of $A\,B$ being known, we have by Eq. 1,

$$F\,A : F\,B :: x : y$$

Subtracting

$$F\,A : F\,B - F\,A :: x : y - x$$

so that

$$F\,A : A\,B :: x : y - x$$

whence $$F\,A = \frac{A\,B \times x}{y - x} \ldots\ldots\ldots \text{Eq. 4.}$$

Let us now assume that $B\,F$ and $B\,P$ are each 20 inches long, while $A\,B$, $B\,C$, $A\,T$ and $C\,T$ are each 10 inches long, these being the general proportions when the several arms are fully extended. From Eq. 2 we have

$$y = \frac{B\,P \times x}{A\,T}$$

and assuming x to be 1, we have

$$y = \frac{20 \times 1}{10} = 2,$$

therefore the proportion of x to y is the same as 1 to 2, in which case the reproduction at P of a drawing placed under the tracer T, would be twice as large as the original.

Assuming this proportion to be the correct one, we have for $F\,A$ according to Eq. 4.

$$F\,A = \frac{A\,B \times x}{y - x} = \frac{10 \times 1}{2 - 1} = 10 \text{ inches},$$

which is the length already assumed.

This form of Pantograph will not therefore answer for reproductions *less than twice as large as the original*, such as 2 to 3 or 3 to 4, seeing that the arms $F\,A$ and $A\,T$ would each have to be longer than 10 inches.

Figure 2 represents the same instrument set to a different proportion, but on examination it will be found that the same formulæ hold good. Thus, the ration of x to y is taken as 1 to 3, whence

$$F\,A = \frac{10 \times 1}{2} = 5 \text{ inches}$$

and

$$A\,T = \frac{20 \times 1}{3} = 6\tfrac{2}{3} \text{ inches.}$$

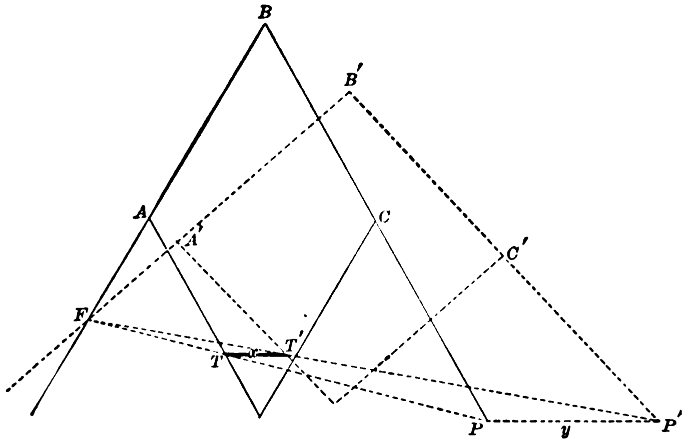

Fig. 2.

It is well to notice that in all positions in both Figs. 1 and 2, the three points F, T and P, as well as F, T^1 and P^1 are necessarily in a straight line, also that in both figures

$$\left.\begin{array}{l} F\,T : F\,P \\ F\,T : F\,P^1 \end{array}\right\} :: x : y$$

so that if these or any other proportions be laid off on the drawing board in a straight line, the instrument can be *set* by holding the pencil at one extremity of this line and bringing the tracer and the fulcrum to their respective positions T and F.

If the arms $A\ F$ and $A\ T$ were divided into 100 or any other convenient number of equal parts, ($A\ B$ being supposed to be graduated like $A\ F$, and $B\ P$ into twice the same number of parts) and these were numbered downwards from A towards F and T, then the formulæ would at once give the positions to which the fulcrum and tracer should be set, these being generally attached to sockets which slide upon their repective bars, or as is sometimes the case, the bar $A\ F$ slides within the bar $A\ B$. In all the different methods of adjustment, the principle is the same, the distance from A to F and from A to T being regulated by the proportion x to y. For greater accuracy a vernier might be attached to the sockets, so that the length of the bars $A\ F$ and $A\ T$ would be practically divided into 1000 parts each.

When the Pantograph is used for reducing drawings, the same formula will serve, the only difference being that the Tracer and Pencil are reversed.

In our next we shall examine the conditions which govern the Pantograph used for the *Reverse* method, which is generally adopted for the better class of work. For elementary work the Erect method is simpler and more convenient, and is consequently more used in the cheaper class of instruments, although it is considered by many as superior to the other, being less shaky owing to its being more self-contained and more concentrated in its movements.

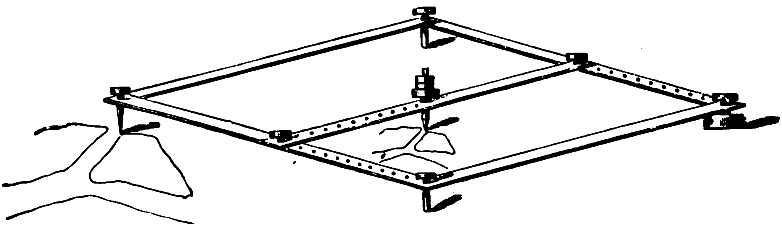

Fig. 3.

Figures 3 and 4 represent Pantographs made on the principles described, the copy being drawn erect with either. Fig. 3 is a substantial instrument, and as the arms are all jointed at each end, the motions are comparatively steady, and reductions, if made with care, will be well proportioned. As the pencil however is placed almost in the centre of the instrument, it somewhat obstructs the view, and renders observation of the progress being made more difficult. This is a good instrument for reducing, but is unsuited for enlarging.

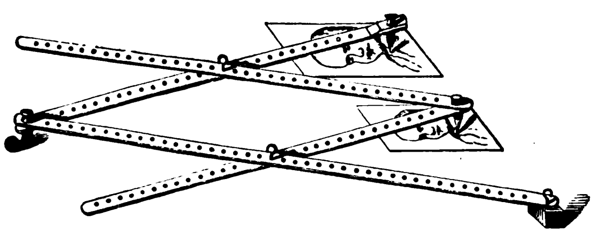

Fig. 4.

Figure 4 serves to reduce or enlarge, but it should be noted that in the latter case any unsteadiness of the hand in tracing the outlines of the original, or any vibration of the several parts of the instrument, are reproduced in the copy in the same proportion as the setting of the Pantograph, while in reducing any divergence from the lines of the original is diminished in the reproduction in the same proportion.

A WONDERFUL TELESCOPE.

IF NOTHING HAPPENS to mar the success of the inventor, there will be on exhibition at the World's Fair something in the way of a telescope which will outdo all previous attempts at perfection in this interesting and important instrument. The inventor is a South American gentleman, and he is at present in Washington, in consultation with scientific men and officials, as to the best mode of procedure. The telescope will be large and very powerful. In the mechanism of this wonderful piece of work a new medium is employed in the first place for the mirrors themselves, and then for focal adjustment; instead of the present method of moving the eyepiece the mirror itself is moved.

The inventor has already constructed an instrument 25 inches in diameter, which in an exhibit in New York City recently showed marvellous power. An instrument of four yards diameter will only weigh 200 pounds, and unless the inventor has made a very great miscalculation will have such power as to bring the moon within one mile of the earth, and allow observers to finally determine the structure and question of the practicability of life existing on that luminary.—*The Manufacturers' Gazette.*

SOLAR PARALLAX.

The values of Solar Parallax have been deducted from heliometric observations made by the German expeditions which observed the transit of Venus in 1874 and 1882, by Mr. Auwers of Berlin.

The 307 observations made in 1874 give a value of $8''.873 \pm 0''062$; and the 444 observations made in 1882 give very similar results, $8''.883 \pm 0''037$.

The probable value, obtained from these two series of observations is $8''.880$ with a mean error of $\pm 0''.032$ and a probable error of $\pm 0''.022$.

(Revue Scientifique.)

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

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LIGHT: ITS REFLECTION AND REFRACTION.

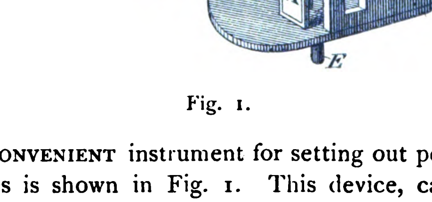

Fig. 1.

ANOTHER CONVENIENT instrument for setting out perpendiculars and measuring angles is shown in Fig. 1. This device, called the Amagat Graphometer, illustrates another application of the law of double reflection, and is similar both in principle and general arrangement to the Sextant. It consists of a small brass case, $2\frac{3}{4}$x$2\frac{3}{4}$x$1\frac{3}{8}$ inches, near the centre

of which is pivoted a small mirror *A*, called the Index Glass, to whose axis is attached an arm *C*, 2 inches long, called the index bar, with a vernier at its extremity. On the upper edge of the case is an arc *D* of 70 degrees, divided to 30 minutes, and reading with the vernier to single minutes. Another mirror *B*, called the Horizon Glass, is pivoted in the side of the case, and is susceptible of circular motion upon its axis by means of a lever *E* so that the reflected image of one object may be brought into coincidence with the direct image of another object, and their horizontal angular distance measured although the two objects themselves are *not in the same plane.* A window in the side of the case is provided for sighting the direct object either above or below the mirror *B*, when, if the vernier be set to zero of the arc, and the index arm be correctly adjusted, the reflected image of the same object will be seen in the horizon glass *B* in coincidence with the direct object above or below.

Suitable provision is made for adjusting the index arm by means of two screws, and the above test should always be made before using the instrument, and if it is found to be out of adjustment, the index error should be rectified, or a + or — index correction, called the *I. C.*, used. In making this test it is well to view some *distant* object, a star being probably more suitable than anything else. A small adjustable stop at the end of the graduated arc allows the index arm to be quickly set to zero.

When using the instrument, it is generally taken in the left hand and turned over with the arc and vernier arm beneath, its position in the figure being reversed in order to show its working parts. The vernier is then set to zero, and the left hand object sighted directly through the window and above or below the mirror *B*. When this is done turn the index arm gently round until the reflected image of the second object, if in the same horizontal plane, is brought into coincidence with the direct object. The vernier will then indicate the angle of inclination of the two mirrors, double which will be the angular distance of the two objects. If the two objects are not in the same horizontal plane, they must be brought to coincide by turning the two mirrors simultaneously or alternately until they so appear. A little practice will render this very easy. When the two images coincide, then half their angular distance, reduced to the same horizontal plane, may be read off on the graduated arc by means of the vernier.

The following are a few of the many uses to which this instrument may be put:—

1. To set out perpendiculars.
2. To measure the horizontal angular distance of two objects not in the same horizontal plane.

3. To measure a line when one or both ends are inaccessible.
4. To measure heights.
5. To observe altitudes with an artificial horizon.

We shall in our next explain the principles upon which the use of this simple instrument depends, and also give a few practical examples of what may be done with it.

As we have several times referred to the reflected image of objects seen in the mirror, we conceive that we cannot do better than close this description of the Graphometer, which is the representative of several other instruments, differing in form and general arrangements, but having the same objects in view, by citing a few remarks from the pen of Prof. P. G. Tait He says in his article on LIGHT in the *Encyclopedia Britannica*,—

> "We may assume here—what is indeed evident from the rectilinear propagation of light—that objects are rendered visible to the eye by rays *diverging* from them. Hence, if we have a set of reflected or refracted rays diverging from any point, or diverging as if they came from any point, they will convey to the eye the impression of the existence of a luminous source at that point. The eye, in fact, can only tell us, what effect is produced upon it, *i. e.* what sort of mechanical action it is subjected to. Its indications must therefore depend only upon what reaches it, and in no other sense whatever upon the source or the path of light. This point from which rays diverge or appear to diverge, is called an *image*.
>
> The image of any point in a plane mirror is found by drawing from the point a perpendicular on the mirror and producing it until its length is doubled.
>
> The extremity of the line so drawn is the image of the point; or, in other words, rays proceeding from the point diverge after reflection as if they came from the image so found. The image in this case is called *virtual*, to distinguish it from cases where it is *real*, —the distinction being that the rays have actually passed through a real image, while they only appear to come from a virtual one."

THE VALUE OF "PI."

A WRITER IN A New York paper related recently the wonderful rediscovery of a fact, known more than 2000 years ago, but meanwhile either lost, forgotten or perhaps even set aside as N. G. By means of this ancient secret, now so strangely brought to light again, it would appear that the area of a circle is equal to

$$\text{diameter}^2 \times 0.8$$

whence the resussitated value of π becomes 3.2 instead of 3.14159. . . .

It is our intention in the present article to examine a practical method employed more than 2000 years ago by Archimedes for solving the same problem, and which is as accurate and practicable to-day as it was then.

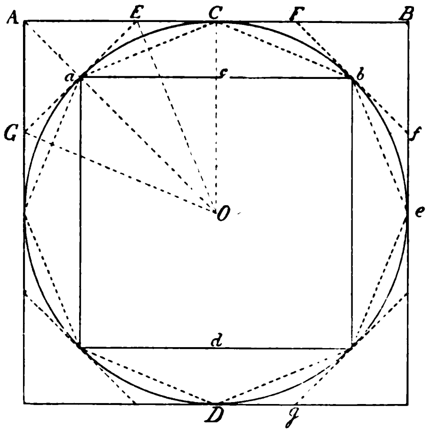

Fig. 1.

It is self-evident that in Fig. 1 the area of the circle $a\,C\,b\,e\,D$ will be somewhere between the area of the inscribed square $a\,b\,d$ and the area of the circumscribed square $A\,B\,D$, that is, it will be greater than $a\,b^2$ and less than $A\,B^2$. It will also be self-evident that the area of the same circle $a\ C\ b\ e\ D$ will lie somewhere between the area of the inscribed octagon $a\,C\,b\,e\,D$ and the area of the circumscribed octagon $G\,E\,F\,f\,g$, and not only so, but the area of these octagons clearly approaches more nearly the area of the circle than does the area of the squares. We can now well see that if we were to continue doubling the number of sides of the inscribed and circumscribed polygons, the area of each succeeding pair of polygons would more and more nearly approach the area of the circle, so that if this process were continued sufficiently far, the areas of the three figures would for all practical purposes be alike. It is therefore now only necessary to show how the areas of these inscribed and circumscribed bisected polygons may be obtained from the original inscribed and circumscribed squares.

Let in Fig. 1

p represent the area of the inscribed square $a\,b\,d$
P " " " circumscribed square $A\,B\,D$
p^1 " " " inscribed octagon $a\,C\,b\,e\,D$
P^1 " " " circumscribed octagon $G\,E\,F\,f\,g$,

then

$a\,b$ is a side of the inscribed square,

$A\,B$, parallel to $a\,b$, is a side of the circumscribed square,

O is the centre of the corresponding circle,

$a\,C$ is a side of the inscribed octagon, and

$G\,E$ and $E\,F$ are sides of the circumscribed octagon.

It is clear that the area of $c\,a\,O$ bears the same proportion to the square p that the area of $C\,A\,O$ does to the square P, and further that the area of $C\,a\,O$ bears the same proportion to the octagon p^1 that the area of $C\,E\,a\,O = G\,E\,O$ does to the octagon P^1, seeing that they are each and severally the eighth part of their respective squares and octagons.

We have now before us two distinct problems, the first one of which is to find the relation of the area of the inscribed octagon p^1 to the areas of the inscribed and circumscribed squares p and P; whilst the second problem must furnish the relation of the area of the circumscribed octagon in terms of the areas of any or all of the three now known polygons p, p^1 and P.

1st Case. Triangles having equal altitudes are to each other in the proportion of their bases, therefore

$$\triangle\, c\,a\,O : \triangle\, C\,a\,O :: c\,O : C\,O,$$

and consequently from the preceding hypothesis it is evident that

$$\triangle\, c\,a\,O : \triangle\, C\,a\,O :: p : p^1$$

whence it follows that

$$p : p^1 :: c\,O : C\,O \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1.}$$

Further $$\triangle\, O\,C\,a : \triangle\, O\,C\,A :: a\,O : A\,O$$

and $$\triangle\, O\,C\,a : \triangle\, O\,C\,A :: p^1 : P$$

whence $$p^1 : P :: a\,O : A\,O, \ldots\ldots\ldots\ldots \text{Eq, 2.}$$

As, however, $a\,c$ and $A\,C$ are parallel, we have

$$c\,O : C\,O :: a\,O : A\,O$$

and as ratios that are equal to the same ratio are equal to each other

$$p^1 : P :: c\,O : C\,O$$

and consequently

$$p : p^1 :: p^1 : P$$

whence $$p^1 = \sqrt{p \times P} \ldots\ldots\ldots\ldots \ldots \text{Eq. 3.}$$

2nd Case. By the preceding theorem

$$\triangle\, C\,O\,E : \triangle\, E\,O\,A :: C\,E : A\,E$$

Now, as the line which bisects the vertical angle of a triangle divides the base into two segments which are proportional to the adjacent sides, and as $O\,E$ bisects the angle $C\,O\,A$, then

$$C\,E : A\,E :: C\,O : A\,O \text{ also}$$

$$C\,E : A\,E :: c\,O : a\,O$$

But $aO = CO$, and from Eq. 1.

therefore

$$p : p^1 : : cO : CO$$

$$\triangle\, COE : \triangle\, EOA : : p : p^1 \ldots\ldots\ldots \text{Eq. 4}$$

and by composition

$$COE : COE + EOA : : p : p + p^1$$

that is

$$COE : COA : : p : p + p^1.$$

As equimultiples of two quantities have the same ratio as the quantities themselves, so

$$2\, COE : COA : : 2\,p : p + p^1$$

But
$$2\, COE = COaE$$

and by the hypothesis laid down at the outset

$$COaE : COA : : P^1 : P$$

therefore
$$P^1 : P : : 2\,p : p + p^1$$

whence
$$P^1 = \frac{2\,p\,P}{p + p^1} \ldots\ldots\ldots \text{Eq. 5.}$$

To reduce this now to practice, let us assume, Fig. 1, the radius of the circle $aO = 1$, then the side of the incribed square $a\,b = \sqrt{2}$, and the area will be $2 = p$. Likewise the side of the circumscribed square $A\,B = 2$ Radius; and the area $4 = P$.

Now, according to Eq. 3 the area of the inscribed octagon or

$$\begin{aligned} p^1 &= \sqrt{p \times P} \\ &= \sqrt{2 \times 4} = 2.82843 \ldots \end{aligned}$$

and according to Eq. 5 the area of the circumscribed octagon or

$$\begin{aligned} P^1 &= \frac{2\,p\,P}{p + p^1} \\ &= \frac{2 \times 2 \times 4}{2 \times 2.82843} = 3.31371 \ldots \end{aligned}$$

We now proceed in the same manner to obtain the areas of the inscribed and circumscribed polygons of 16 sides, thus

$$\begin{aligned} p^1 &= \sqrt{2.82843 \times 3.3171} \\ &= 3.06147 \ldots \end{aligned}$$

$$\begin{aligned} \text{and } P &= \frac{2 \times 2.82843 \times 3.31371}{2.82843 + 3.06147} \\ &= 3.18260 \ldots \end{aligned}$$

It is clear, therefore, that the area of the circle whose radius is 1, will be less than 3.18260 and greater than 3.06147 . . . and if this process be continued the sides in each case being bisected, we obtain the following results :—

Number of Sides.	Area of Inscribed Polygon.	Area of Circumscribed Polygon.
4	2.00000	4.00000
8	2.82843	3.31371
16	3.06147	3.18260
32	3.12145	3.15172
64	3.13655	3.14412
128	3.14033	3.14222
256	3.14128	3.14175
512	3.14151	3.14163
1024	3.14157	3.14160
2048	3.14159	3.14159

It must, therefore be self-evident that the area of the circle whose radius is unity must be 3.14159 correct to five places of decimals.

Archimedes, who was born at Syracuse, in Sicily, about 287 B.C., and who was slain 212 B.C., was the greatest mathematician of his day, and he wrote several able treatises, a few of which have been preserved. One of them on the *Measure of the Circle* is a short book of three propositions, in which he proves

1st, that the area of a circle is the same as that of a triangle whose base is equal to its circumference, and its height equal to its radius;

2nd, that the circumference of a circle exceeds 3 times its diameter by a fraction which is less than $\frac{10}{70}$ and greater than $\frac{10}{71}$, that is, the value of π lies between 3,140845 . . . and 3.142857 . . .; and

3rd, that a circle is to its circumscribed square nearly as 11 to 14.

He reached the above conclusions by computing the areas of an inscribed and a circumscribed polygon, each one having 96 sides.

Vieta, Van Ceulen, Sharp, De Lagny, Dr. Clausen and many others have since carried the value of π much further, the latest effort being that of Richter in 1854, who computed it to 500 places of decimals.

In conclusion, we may state that the best simple approximation to the value of π, and one which is correct for all practical purposes, is the ratio of 113 to 355, which is equivalent to

$$1 : 3,1415929 \ldots$$
$$\text{while } \pi = 1 : 3.1415926 \ldots$$

the difference being equal to one inch in 150 miles.

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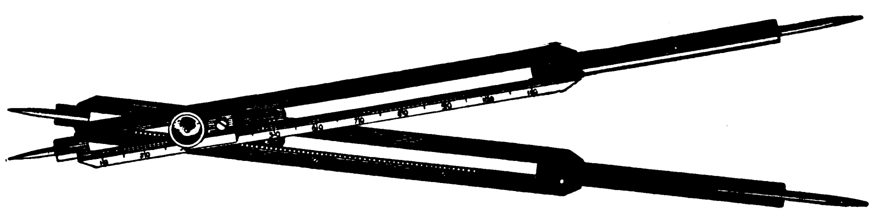
All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

UNIVERSAL PROPORTIONAL DIVIDERS.



WE REGRET that owing to a disappointment on the part of our engraver, we were unable to give our readers last month a sketch of the above instrument. We do so now and hope it will enable them the better to understand the principles upon which it is made and the methods of using it.

THE PANTOGRAPH.

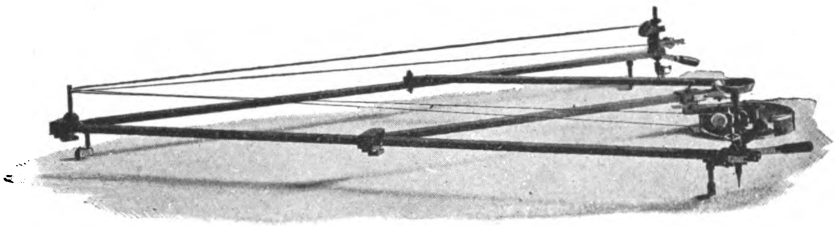


Fig. 1.

WE EXPLAINED in our last the principles of that form of Pantograph used for the *Erect* method; we now come to the *Reverse* method, which is that generally adapted for the better class of instruments.

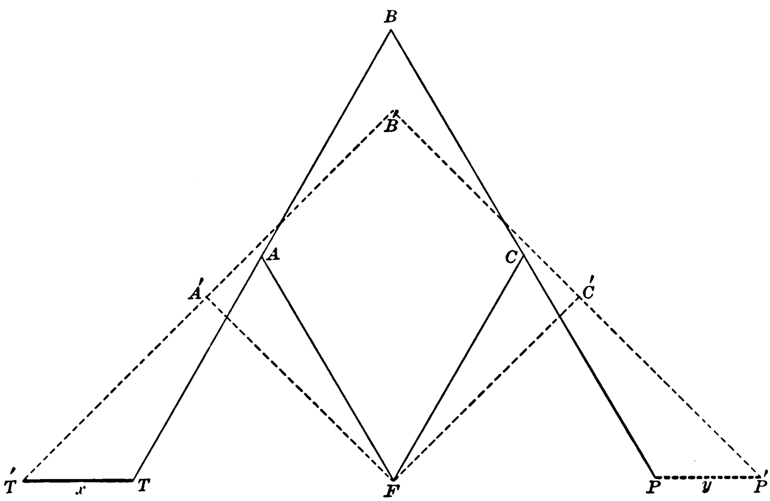


Fig. 2.

Figure 2 represents an instrument of this kind, set for reproducing drawings on the same scale as the original, $B\,T$ and $B\,P$ being the long arms, $A\,F$ and $C\,F$ the short arms, and F the fixed fulcrum. The instrument, as shown by the solid lines, is as it is set before commencing work. Another position is shown by the dotted lines, the tracer having been carried from T to T^1 and the pencil following a contrary but equally long course from P to P^1.

By similar reasoning to that employed for the erect method, and according to the same theorem, we have

$$TA : TB :: TF : TP$$

whence $$TA : TB - TA :: TE : TP - TF$$

or $$TA : AB :: TF : FP.$$

Likewise $$T^1 A^1 : A^1 B^1 :: T^1 F : F P^1;$$

But $$T^1 A^1 = TA \text{ and } A^1 B^1 = AB$$

therefore, and by subtracting

$$TA : AB :: T^1 F - TF : FP^1 - FP$$

that is $$TA : AB :: x : y$$

whence $$TA = \frac{AB \times x}{y} \quad . \; . \; . \; . \; . \quad \text{Eq 5.}$$

We have thus for any ratio the length of the tracer arm from the joint A to the tracer point T, in terms of the invariable length $A B$.

Again we have

$$TA : TB :: TF : TP$$

and $$T^1 A^1 : T^1 B^1 :: T^1 F : T^1 P^1.$$

But $$T^1 A^1 = TA \text{ and } T^1 B^1 = TB,$$

therefore $$TA : TB :: \begin{cases} TF : TP \\ T^1 F : T^1 P^1 \end{cases}$$

whence, and by subtraction

$$TA : TB :: T^1 F - TF : T^1 P^1 - TP$$

that is $$TA : TB :: x : x + y;$$

but $$TA : TB :: AF : BP$$

therefore $$AF : BP :: x : x + y$$

whence $$AF = \frac{BP \times x}{x + y} \quad . \; . \; . \; . \; . \; . \; . \quad \text{Eq. 6.}$$

By this equation we obtain the distance of the fulcrum F from the joint A in terms of the invariable length $B P$.

In these Pantographs the positions of the Tracer T and the Fulcrum F as shown are movable on their respective bars, while the Pencil P is fixed. As, however, the fulcrum cannot be made to coincide with the joint of the arms $A F$ and $C F$, it is placed a little higher up the arm, $A F$ toward A, necessitating likewise the shortening of the arm $B P$. Thus, suppose we have $A T = A B = B C = 10$ inches, and $A F = 9\frac{1}{8}$, then we have, by transposing Eq. 6

$$BP = \frac{AF \times (x + y)}{x} = \frac{9\frac{1}{8} \times 2}{1} = 18\frac{1}{4} \text{ inches.}$$

This length of the arm $B\ P$ to the pencil P becomes therefore a fixed length, and when it is required to enlarge drawings, the positions of the tracer and fulcrum are brought nearer to the joint A, in accordance

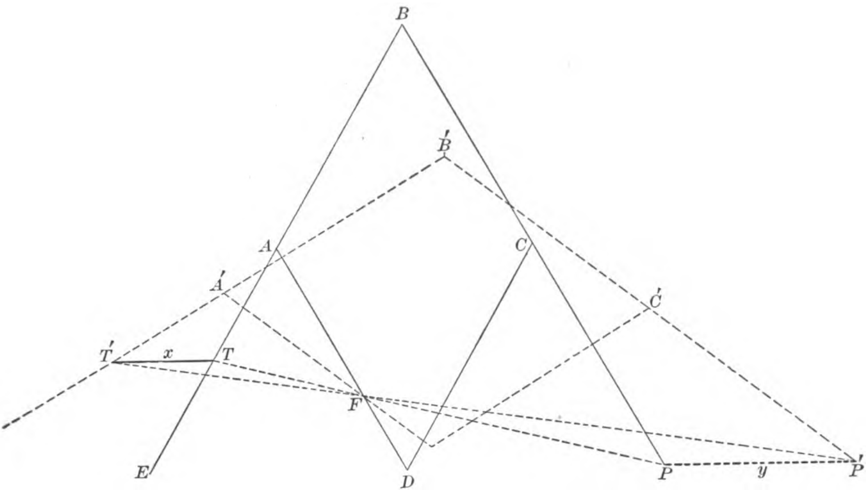


Fig. 3.

with the formulæ, thus in Fig. 3, the Pantograph is set to enlarge drawings in the ratio of 1 to 2, then we have by Eq. 5,

$$T\ A = \frac{10 \times 1}{2} = 5 \text{ inches}$$

and by Eq. 6,

$$A\ F = \frac{18\frac{1}{4} \times 1}{1 + 2} = 6\tfrac{1}{12} \text{ inches.}$$

It will be also noticed in the case of instruments for the *Reverse* method, that in all positions, and with correct settings, the three points T, F and P as well as T^1, F and P^1 are always in a straight line, and also that

$$\left.\begin{matrix} T\ \ F : F\,P \\ T^1\,F : F\,P^1 \end{matrix}\right\} :: x : y$$

The arms $A\ T$ and $A\ F$ are generally marked to give settings for a few fixed ratios, but in the best instruments of this kind, they are fully graduated, being divided into a given number of equal parts, (100 or any other suitable number) so that the instrument may be at once set for any ratios x to y. Such an instrument is the one shown in Fig. 1, for reducing and enlarging, which is well made, carefully finished, well balanced in all its parts, and embodies all the latest improvements. The fulcrum is fixed to a socket which slides on the arm $A\ F$, while the pencil is placed in the fixed socket P of the arm $C\ P$, when used for *enlarging*, and in the socket T

which slides on the arm *A T*, when used for *reducing*, the tracer in the latter case replacing the pencil in the socket *P*. An improved pencil lifter is also attached to the two sockets *T* and *P*, so that any parts of the original may be passed over without the copy being marked. The arms are made of hollow square brass tubes, which however do not telescope as do those of the cheaper instruments, in which the socket *T* is fixed to the bar *A T*, and this when required to be shortened, slides within the bar *A B*.

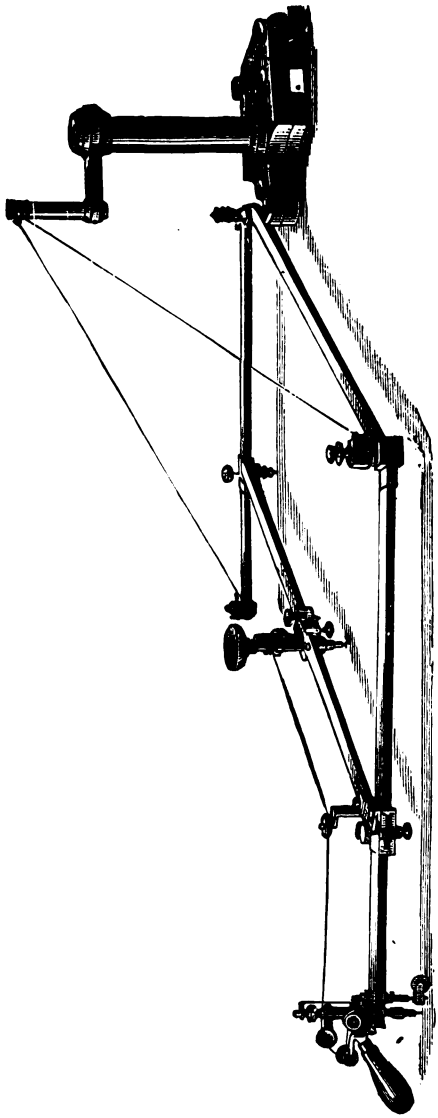


Fig. 4.

A very superior instrument where great precision is required, is shown in Fig. 4, which represents a Suspended Pantograph, for reducing and enlarging. The bars, which are composed of square brass tubes, are suspended from a solid standard in order to remove the friction caused in the ordinary instruments by the rolling of the castors on the paper. The standard is provided with a spirit level and leveling screws so that it may be adjusted to a perfectly horizontal position. The bars are graduated from end to end and very fine divisions may be read off by means of verniers attached to the sliding sockets, so that settings may be easily obtained for any proportion other than the 24 marked on the instrument. Micrometer adjustments enable these settings to be effected with extreme accuracy. This Pantograph is of the best construction, carefully and well made, highly finished, and may be thoroughly relied upon for good and accurate work.

We bring these remarks to a close by observing that the ratio obtained by means of the *Settings* marked on the arms of the ordinary Pantograph, are those of the *lines* of the original to the *lines* of the copy. In some cases, however, it may be desired to reproduce a drawing so that the AREA of the copy may bear a given proportion to the AREA of the original. This may be very easily done with a fully graduated instrument as shown in Fig. 1. Thus, if we wish to reproduce the plan of a certain plot so that the area of the original shall be to the area of the copy in the proportion of 4 to 9, we have

$$T\,A = \frac{10 \times \sqrt{4}}{\sqrt{9}} = 6\tfrac{2}{3} \text{ inches}$$

and

$$A\,F = \frac{18\tfrac{1}{4} \times \sqrt{4}}{\sqrt{4} + \sqrt{9}} = 7.3 \text{ inches,}$$

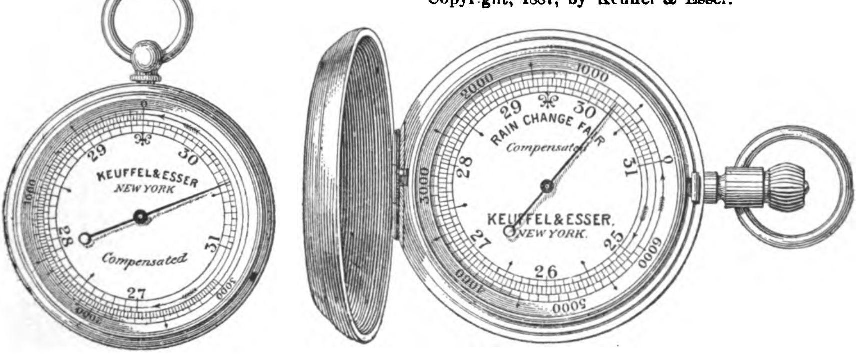
and similarly for any other proportions of *areas*.

It will be at once seen that this method is similar to that used for the scale of *Planes* of the Proportional Dividers, described in No. 7 of Volume I of THE COMPASS.

ANEROID BAROMETERS

FOR MEASURING HEIGHTS AND ATMOSPHERIC PRESSURE.

"Copyright, 1887, by Keuffel & Esser."



Plain directions for measuring heights with the Aneroid Barometer.

The pressure of the atmosphere upon the earth's surface diminishes as we ascend, but this diminution is not strictly proportional to the difference of elevation. It follows however laws which are known, from which tables of heights have been compiled.

Differences of temperature affect the density of the air and consequently also exert a certain influence upon the barometer, which requires to be taken into account when differences of altitude are being determined by the aid of this valuable instrument.

The table most generally accepted is that prepared by Prof. Airy, late Astronomer Royal of Great Britain, in which 31 inches of pressure represents the zero of altitude, assuming that the average temperature is 50° Fahrenheit.

There is on most Aneroid Barometers a movable ring outside the dial, which can be generally turned round by the cover. On this ring is a graduated scale of feet, beginning with 0 and ranging up to 3000 to 18000 feet, according to the instrument. This scale is generally supposed to be graduated in accordance with Airy's table.

To ascertain the difference of elevation between two points of observation, proceed as follows:

Set zero of the movable scale of feet to 31 inches of the barometrical scale, and note the reading of the scale of feet at the lower station as indicated by the position of the needle on the movable ring. When the ascent is terminated, note again the reading of the scale of feet as shown by the altered position of the needle; the difference of the two will give the difference of elevation of the two stations, *without* any allowance or correction for the difference of temperature between the lower and the upper stations. The correction for temperature is obtained by means of the formula

$$D = \frac{900 + T + t}{1000},$$

where T and t are the respective temperatures in degrees Fahrenheit at the lower and upper stations. The difference of height already ascertained must then be multiplied by D.

The complete formula becomes

$$\text{Difference of elevation} = (H - h) \times \left(\frac{900 + T + t}{1000}\right),$$

where H and h represents the readings on the scale of feet at the two stations.

Example:—Needle at lower station = 29.8 inches.
" " upper " = 27.4 "

Thermometer at lower station = 73° F.
" " upper " = 68° F.

Equivalent of 27.4 inches = 3365 feet.
" " 29.8 " = 1075 "

H— h = 2290 feet.

then according to formula we have

$$2290 \times \frac{900 + 73 + 68}{1000} = 2290 \times \frac{1041}{1000} = 2383.89 \text{ feet}$$

as the difference of elevation between the two stations; the difference without correction for temperature being 2290 feet.

Note. The instrument should not be influenced by the heat of the hand nor by the rays of the sun.

The Barometer should *always* be held in the same position, preferably with the face horizontal.

The instrument should always be tapped gently with the finger when an observation is taken.

Aneroid Barometers are generally marked *compensated.* This merely indicates that the *instrument itself* is free from errors arising from changes of temperature, and in no ways refers to the difference of temperature at the two stations, which must always be taken into account and calculated according to the formula.

The foregoing PLAIN DIRECTIONS have been written for general use with that large class of pocket Aneroid Barometers, whose scale of feet is supposed to be graduated in accordance with Airy's tables, and are intended more especially for the traveller or tourist, where extreme accuracy is not a *sine qua non.*

The difference of height between two stations, obtained as described, can, however, after all only be looked upon as an approximate one, as the barometer is subject to other variations besides those named, which however are not generally taken into account in ordinary cases by the topographer. These variations result from differences of latitude, atmospheric disturbances and the humidity of the air, as well as from causes inherent in the instrument itself.

The formula given assumes that the air is in a perfect and continuous state of statical equilibrium from the beginning to the end of the observations, and that consequently the difference of pressure is only due to the difference of elevation between the two stations, and that the modifying effect of the difference of temperature is uniform and also proportionate to the difference of elevation. As however the air is rarely, if ever, in such a condition, it is necessary that the different causes of variation be eliminated as far as possible by means of repeated observations, when, under favorable circumstances, the mean of the several barometrical and thermometrical readings may be relied upon to give fairly accurate results.

Instrumental errors must be ascertained by frequent comparison with a standard mercurial barometer; and here it is perhaps well to remark, a cheap instrument should never be used for measuring altitudes, as the graduations are rarely correct, the scale of feet, which is not one of equal

parts, being frequently so made. In such cases, and in fact at all times, it is well to use the barometrical scale, even if the scale of feet is also used. Recourse must then be had to Airy's table already named, or to some of the numerous formulæ devised for the purpose. The following one is very frequently used,

$$\text{Difference of Height in Feet} = 60000\,(\text{Log}\,B - \text{Log}\,b) \times \left(\frac{840 + T + t}{900}\right)$$

Other formulæ are those of Francis Galton of the Royal Geographical Society, the one of Col. Williamson, U. S. A , and an easy approximate rule by J. H. Belville of the Royal Observatory, Greenwich, based upon an average temperature of 55°. The three necessitate the use of tables, whereas the following modification of Belville's by Mr. T. H. Gribble, is complete in itself:—

$$\text{Difference of Height in Feet} = K \times \frac{D}{S},$$

where D = difference of barometrical readings in inches,
S = sum " " " " "
K = coefficient of temperature
= 48753 + (116 × Mean temperature).

The results obtained by this formula are a mean result between those of the English and American formulæ, and the calculation is so simple that it can be almost entirely worked out with the slide-rule.

We have said that when accuracy is desired, recourse should be had to repeated observations. Not only so, but it is advisable to use two instruments, and to have the observations taken simultaneously at each station by separate observers. When this is impossible, then the observation should be repeated at the first station after the one at the upper station has been taken, and the mean of the two used in the formula, on the assumption that it gives the correct barometric and thermometric conditions at the lower station at the time when the observation was being taken at the upper one.

We close with a comparative example taken from Mr. Gribble's book on "Preliminary Survey."

Barometer 28″ and 22″
Thermometer 60° " 40°

Difference of height

By Airy's tables........	6571.5 feet.
" Col. Williamson's rule............	6527 5 "
" Francis Galton's rule.............	6552.7 "
" Gribble's rule...................	6546.4 "

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

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ENGINEERING AND SURVEYING INSTRUMENTS.

Hand Levels.

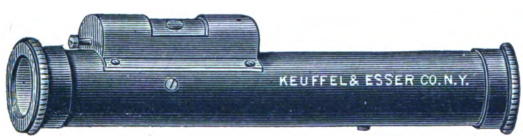


Fig. 1.

Besides the expensive instruments already described, with revolving centres, leveling attachments and telescopes of considerable magnifying power, another class of Levels is much used for certain kinds of work where a much lesser degree of accuracy suffices.

Figure 1 is a half-size representation of Locke's Hand Level, which is probably the simplest instrument of this class. It consists of a brass or German silver tube about 5 inches long, the right of which, as shown above, is the eye piece, formed by a simple disc with a glazed sight hole in it about one-fortieth inch diameter. To the upper side of the

other end of the tube is attached a small spirit level incased in a brass frame tube, the under portion of which is cut away, as is also the corresponding portion of the main tube, to the same extent as the upper visible portion of the bubble tube.

Beneath the bubble tube, and immediately under and across the centre of its curvature is a fine cross-wire, attached to a small plate which slides in the bubble frame and can be adjusted by means of the small screw shown to the left of the bubble frame, so that its position may be accurately set immediately under the centre of curvature of the bubble tube. Under this centre of curvature and occupying half the vertical width of the main tube, there is fixed a small prism, so placed in relation to the line of sight, that on looking through the sight hole, the reflection of the cross-wire above can be seen across the mirror, and when the instrument is held horizontally, the reflected image of the bubble is seen in coincidence with the wire. In some Hand Levels a mirror is substituted for the prism. The result is identical if the instrument is tested and adjusted before using.

The sight disc is attached to one end of a draw-tube about 2 inches long, to the other end of which is fixed the half of a plano-convex lens, which can be adjusted so as to render the reflected image of the cross-wire clear and distinct.

From this description it will be clear that if the Hand Level is held up before the eye, the objects which are seen through it directly and in coincidence with the reflected image of the cross-wire, when this is seen to cut the centre of the level bubble, are on the same level as the observer's eye.

The uses of such an instrument are numerous, and will readily suggest themselves. It is of course merely a rough and ready kind of level, but for preliminary surveys or reconnaissances and for contouring will be found very useful. It may even be employed by the tourist of a scientific or observing turn of mind, for ascertaining differences of elevation as he walks along on pleasure bent;—thus, by sighting a stone or other distinct object on the road before him, repeating this from the position of the first selected object, and continuing thus to the summit of a pass or hill, he clearly obtains a number of stations along his route, each one of which is as much above the preceding one, as is the height of his eye above the ground; this height then multiplied by the number of stations gives approximately the total difference of elevation.

Figure 2 represents the Abney Reflecting Level and Clinometer which is a much more complete instrument than the Locke Hand Level, as it combines with the level, a Compass and a Clinometer, the one for ascertaining directions and the other for estimating slopes. The Compass is graduated to single degrees and is numbered in quadrants

from 0° to 90°. The bubble tube, instead of being attached to the main tube, as in the Locke Hand Level, revolves on an axis passing through the centre of a vertical arc, which is fixed to the main tube, and the

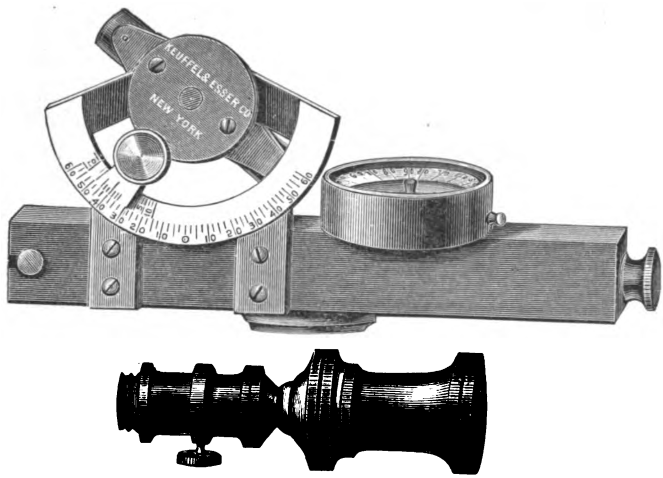


Fig. 2.

bubble, when in the centre of its run, is directly above the mirror or prism in the main tube, and its image is reflected to the eye at the sight hole. The vertical arc is divided to single degrees and numbered each way from the centre from 0° to 60°. A vernier at the end of an arm secured to the bubble tube axis, enables angles of elevation or depression to be read to 10 minutes, and by estimation to 5 minutes; a milled disc, attached to the end of the same axis, serves to bring the bubble to the centre of the tube when sighting objects above or below the sensible horizon, and when so adjusted, the vernier may be clamped by means of the milled headed screw below the disc, and the corresponding angle at once read off. Another series of graduations on the inner edge of the disc gives the slope or grade in terms of the ratio of the base to the perpendicular, as 2 to 1, 1½ to 1, etc., the slope being read off from the outer edge of the vernier plate instead of from its zero point.

The main tube of the Abney Level is square, so that it may be used as an ordinary spirit level, with the further advantage that when it is placed on a sloping surface, the angle of inclination or the ratio of the slope may be at once ascertained. In some instruments the graduations of the arc are carried to 90°, so that by setting the vernier zero to this angle and holding the instrument with its underface against a wall or other object, its perpendicularity may be at once ascertained by the bubble coming to rest in the middle of its run. A combination of a Prismatic

Compass with the Abney Level is also sometimes used and found to answer well, as the magnifying of the graduations of the compass by the prism enables not only half degrees, but also quarter degrees to be easily estimated.

A ball joint and socket for jacob staff, as shown in the figure, are provided with each instrument, so that greater precision in the results may be attained than if it were held in the hand.

It may perhaps not be out of place in this connection to devote a few lines to the consideration of a *level* surface and a *horizontal* line or plane.

We have stated in another article (Adjustments of Surveying Instruments) that the foundation of all such adjustments is *that earth's radius upon which the operator is for the time being located.* This radius, which is an imaginary line proceeding from the earth's centre, through the operator to the zenith, is a *vertical line*, whilst another line or plane continued in all directions at right angles to it, is, as regards *this particular vertical line*, or the point where it cuts the earth's surface or the observer's eye, a *horizontal* line or plane. It will be evident, therefore, that the distance from the earth's centre to this horizontal plane increases as we leave our first station or point of observation, which determined the vertical line.

A *level surface* is, however, at all points of its surface equally distant from the earth's centre, so that a horizontal plane is, by reason of the spherical form of the earth, only *level* for that one point for which it has been ascertained. Leveling, therefore, consists in determining the differing distances from the centre of the earth of different points on its surface, and not their distance above or below a given horizontal plane. For short distances, however, a level surface and a horizontal plane are practically the same, the depression of the former, or the line of *true level* being but 8 inches in a mile, and increasing as the square of the distance, being 32 inches in 2 miles, and so on.

A vertical line is obtained by means of a suspended plumb-line, the attraction of gravity drawing the plumb-bob in the direction of the earth's centre. It is also ascertained by means of a spirit level, which consists of a round glass tube of varying length, curved or having its upper inside surface ground to the from of a perfect arc. This tube is almost entirely filled with ether, leaving a small buble of air, which, by reason of the downward pressure of the liquid, is always forced to the highest point of the arc. A line drawn from the centre of this bubble to the centre of curvature of the arc is then a vertical line, and a line or plane, at right angles to this radius of curvature, or tangent to the middle of the bubble, is a horizontal line or plane, also called the line of *apparent level.*

As a long plumb-line will indicate with much greater accuracy any-

departure of a perpendicular object from the true vertical, so a spirit level with a tube having a long radius of curvature, will be much more sensitive than a tube with a short radius of curvature. This sensitiveness is in direct proportion to the length of the radius of curvature, for

Let $R =$ the radius of curvature of the level tube, in inches,

and $A =$ the length in inches of the arc of the level tube, through which the bubble moves for a difference of level of 1 second,

then we have

$$360^\circ : 1'' : : \left\{ \begin{array}{c} \text{Circumference of} \\ \text{Curvature of} \\ \text{Level Tube} \end{array} \right\} : A$$

or

$$1296000'' : 1'' : : 2 \pi R : A$$

whence

$$A = \frac{2 \pi R}{1296000} = \frac{R}{206265}$$

and

$$R = A \times 206265$$

If, therefore, it is required that the bubble move through 0.1 inch for a variation of elevation of 30 seconds, the radius of curvature of the level tube will be rather more than $57\frac{1}{4}$ feet. It will be at once seen from this that when precise results are desired, what care must be bestowed upon the manufacture of the levels of instruments so used, and that cheapness in such a case generally means untrustworthiness. And not only so, but every other portion of an instrument, as well as its means of adjustment, should be constructed with precision and care proportionate to the sensitiveness of its bubble tube.

THE FLOW OF WATER IN PIPES.

Many formulæ have been devised by various engineers for expressing the relation between the velocity of flow in a pipe and the head required to produce it. Unfortunately all of them are complicated, and cannot be used for mental calculation or in making rapid approximations. It may be noted, however, that in a vast majority of cases arising in practice, the velocity of flow lies between 2 feet and 4 feet per second, and on an average is 3 feet per second. The head required to maintain this latter velocity through a length of clean cast-iron pipe is then

$$\text{Head in feet} = \frac{\text{Length of pipe in feet}}{25 \times \text{diameter of pipe in inches}}$$

and the discharge in cubic feet per minute is very nearly equal to the

square of the diameter of the pipe in inches, the error being under 2 per cent. in excess. Both these calculations are easily performed mentally. For a velocity of 1 foot per second *less* than 3 feet per second, the head must be reduced one-half, and by a proportionate amount for intermediate cases. For a velocity of 1 foot per second *more* than 3 feet per second, the head must be increased by .7 times that required for a 3 foot velocity, and that required for intermediate cases can again be determined by adding a proportionate amount for that required for the 1 foot increase. In this way the head required to maintain through a clean cast-iron pipe a velocity of not less than 2 feet a second, nor more than 4 feet a second, which are the limits usually adopted in practice, can be determined mentally with an accuracy sufficient for 99 per cent. of the cases that arise in an engineer's practice. Having the discharge at a velocity of 3 feet a second it is of course easy to obtain the discharge at any other velocity.—*London Engineering.*

NOTE.—We have frequently used the following original formula and found it to give results almost identical with those obtained by Weisbach's, whilst it has the merit of being very much simpler.

Let L = Length of pipe in feet,
D = Diameter of pipe in inches,
V = Velocity in feet per second,
H = Friction Head in feet,

then

$$H = \frac{L}{1200\,D} \times (4\,V^2 + 4\,V + V - 2).$$

or

$$H = \frac{L}{1200\,D} \times (4\,V^2 + 5\,V - 2)$$

The Formula may be further simplified by reducing it to

$$H = \frac{L \times C}{D}$$

in which C is replaced by the following values, according to the velocity.

Velocity, 1 ft,	C = .00583		Velocity, 6 ft.	C = .1433	
" 2 "	= .02		" 7 "	= .19083	
" 3 "	= .04083		" 8 "	= .245	
" 4 "	= .06833		" 9 "	= .30583	
" 5 "	= .1025		" 10 "	= .3733	

Example.—Find the loss of head for 400 feet of 12 inch pipe, the velocity being 3 feet per second.

$$\text{Loss of Head} = \frac{400 \times (36 + 12 + 1)}{1200 \times 12} = \frac{49}{36} = 1.36 \text{ feet.}$$

which is the same as Weisbach's, whilst *Engineering's* formula gives

$$\text{Loss of Head} = \frac{400}{25 \times 12} = 1.33 \text{ feet.}$$

Weisbach's formula is very frequently used, we believe, by hydraulic engineers in this country, and in some cases where riveted pipes are employed, 20 per cent is added on, so that the formula then becomes

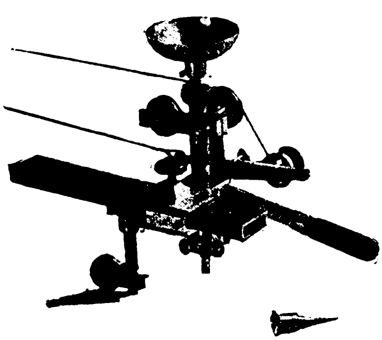
$$\text{Loss of Head} = \frac{L}{1000\,D} \times (4\,V^2 + 4\,V + V - 2).$$

We submit to our readers *Engineering's* formula and our own (which we must say is an empirical one) in the hope that they may be sometimes found to assist speedy calculation.

We have also just completed a Computer, consisting of a dial and revolving disc, which gives *at once* the same loss of head for any pipe from 1 to 100 inches diameter, and 100 to 10000 feet long, with any velocity from 1 to 15 feet per second. The velocities read by tenths from 1 to 8 feet and by fifths from 8 to 15 feet, and the Friction Heads range from .01 to 1000 feet. It also gives the discharge in cubic feet for any velocity and diameter of pipe.

Such an instrument cannot fail, we think, to be of great use where many pipe calculations have to be made, especially as with *any* combination of three terms, the fourth is *at once* found.

(Editor of THE COMPASS.)



THE ACCOMPANYING figure shows in detail the pencil or tracer socket of the Improved Pantograph illustrated in our last number. The handle and the arrangement for lifting the pencil are clearly seen.

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

ADJUSTMENTS OF SURVEYING INSTRUMENTS.

MOST INSTRUMENTS used in surveying consist of parts, pieces or limbs, as they are termed, which should be perfectly parallel or perpendicular to each other, or form with one another angles which may be correctly measured.

These necessary conditions could be largely secured during the process of manufacture if such parts were not frequently required to revolve upon each other, or to be placed in different positions in regard to each other; as however the combinations of movements in such instruments are more or less varied, it is requisite that means be provided for the separate adjustment of each movable piece, so that the whole may be brought into harmony with the main or foundation piece of the combination of parts, which forms the instrument as a complete whole. This piece is in every case supposed to be in coincidence with that earth's

radius upon which the operator is for the time being located, and every other part of the instrument must therefore be either coincident with, or perpendicular to, this radius, or make with it such an angle that its departure therefrom, or its angle of elevation or depression therefrom or from the perpendicular thereto, may be accurately ascertained.

The processes adopted to satisfy these conditions are called the *Adjustments of the instrument*, and they are in almost every case effected by means of the great principle of REVERSIONS. It may be well said therefore, that

REVERSION IS THE SOUL OF ADJUSTMENTS.

We will take a simple case first and then examine the method by which this principle is applied to the adjustments of the several parts of Surveying Instruments.

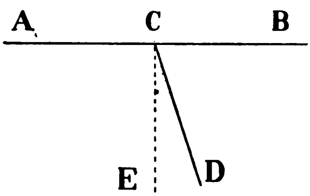


Fig. 1.

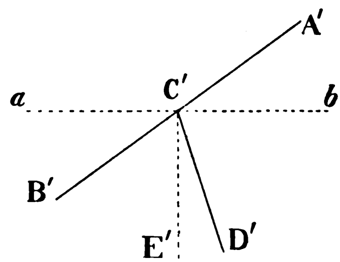


Fig. 2.

We will assume that the line $A\ B$ in Fig. 1 is perfectly horizontal, although it is clearly not perpendicular to $C\ D$,—which consequently is neither vertical nor in coincidence with the earth's radius upon which we are supposed to be standing,—and that by looking along it from A to B we see that it covers a given distant point.

Now supposing that the axial line $C\ D$, and with it the horizontal line $A\ B$, be turned round 180°, then the relative position of the two lines will be as shown in Fig. 2, where $a\ b$ represents the horizontal line $A\ B$ of Fig. 1, covering the same given distant point, but in which $A^1\ B^1$ diverges considerably from the horizontal plane $A\ B$ of Fig. 1.

In the figures let $C\ E$ and $C^1\ E^1$ represent vertical lines, perpendicular to $A\ B$ and $a\ b$, then the angles $D\ C\ E$ and $D^1\ C^1\ E^1$ are the measure of the departure of the axial lines $C\ D$ and $C^1\ D^1$ from a true vertical, and in Fig. 2 the angle $a\ C^1\ B^1$ is the measure of the departure of the line $A^1\ B^1$ from the horizontal plane $a\ b$.

Now $\quad a\ C^1\ B^1 = 180° - (b\ C^1\ D^1 + B^1\ C^1\ D^1);$

but $\quad B^1\ C^1\ D^1 = b\ C^1\ D^1,$

therefore $\quad a\ C^1\ B^1 = 180° - 2\ b\ C^1\ D^1$

Also $$D^1\ C^1\ E^1 = 90^\circ - b\ C^1 D^1$$

therefore

$$a\ C^1\ B^1 : D^1 C^1 E^1 :: 180^\circ - 2\ b\ C^1\ D^1 : 90^\circ - b\ C^1\ D^1$$

or $$a\ C^1\ B^1 : D^1\ C^1\ E^1 :: 2 : 1,$$

so that the angle $a\ C^1 B^1$, or the divergence of the line $A^1\ B^1$ from the horizontal plane $a\ b$ is twice as great as the divergence of the axial line $C^1\ D^1$ from the true vertical $C\ E$.

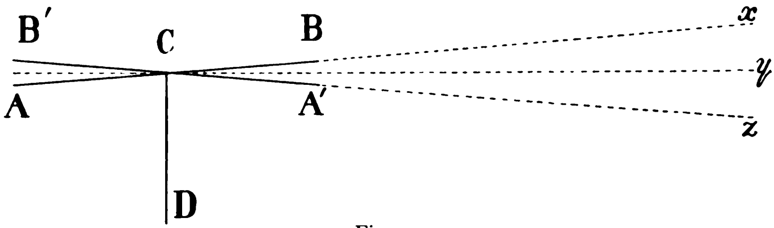


Fig. 3.

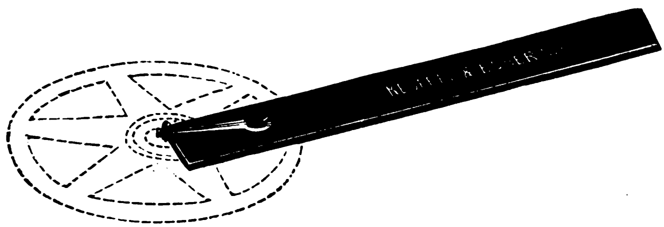
We will now assume that the line $C\ D$ in Fig. 3 is coincident with the earth's radius upon which we are located, that is, that it is a true vertical, and we will also suppose that the line $A\ B$ is perpendicular to it, and that if we look along it we see that it covers the distant point x. If we now turn round 180° the line $A\ B$ and with it its axis $C\ D$, and look from B^1 toward x, we find that a point z is covered by the line $A^1\ B^1$ instead of the first point x. By similar reasoning, therefore, as in the foregoing case, we find that the line $A\ B$ is not perpendicular to $C\ D$, and that $x\ z$ is double the measure of departure of the line $A\ B$ from a true horizontal, or perpendicular to $C\ D$, this horizontal being represented by the middle line $C y$. Such is the principle of Reversion, which at once makes any error of adjustment not only apparent, but determines its quantity, and thus facilitates its rectification.

(*To be continued.*)

THE METRIC SYSTEM IN SPAIN.

The use of the Metric System has for many years been obligatory in Spain, but by a law passed July 8th, 1892, this system is made obligatory throughout her colonies, in all private and public contracts.

THE ECCENTROLINEAD.



THE ABOVE FIGURE shows an instrument which will be found very useful by a certain class of Engineers and Draughtsmen. It consists of an ebony or German silver rule 9 inches long, to which is pivoted about 2 inches from one end an arm, having a socket at its other end, through which a needle point is passed and secured by a set-screw. In some instruments the pivot is also made to slide in a slot, so as to be able to further vary the position ot the needle point.

As the arm is movable on its axis, the needle point can be set and clamped in any position as regards the two straight edges of the rule, consequently if the point is set in the centre of a circle, lines may be drawn to the circumference which originate at any desired lateral distance from the centre, as shown in the figure, which represents a wheel with the spokes drawn from equidistant points on the hub.

It will also be found very useful for drawing a number of lines all radiating from one common centre, as by carefully setting the needle point in line with the straight edge, the exact position of the centre is maintained for every radial line drawn from it, all that is required being to move the outer end of the rule round to each new circumferential position, without regard to the centre, which is accurately maintained throughout by the needle point. Those who have much diagram work to do will thus find it of great assistance.

The edges of the rule are beveled in reverse directions, so that one will serve for pencil work and the other for pen work.

TRANSITS and LEVELS with four leveling screws are generally so constructed, that when, during the operation of leveling up, it is required to raise the right hand side of the instrument, the opposing screws should be turned with both thumbs directed inwards, and the reverse when the left side shonld be raised. This rule may be easily remembered by the short sentence,

Go RIGHT-IN *or else be* LEFT-OUT.

LIGHT: ITS REFLECTION AND REFRACTION. IV.

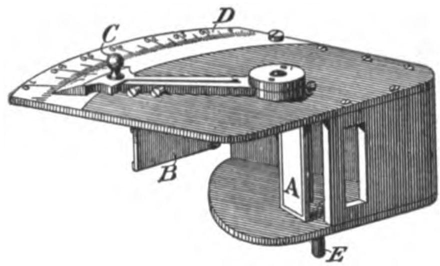


Fig. 1.

IN OUR LAST NUMBER we described the GRAPHOMETER and stated a few of the many uses to which it may be put. We shall now describe the principles upon which its construction is based, and in our next give a few examples illustrative of the methods of using it.

As already stated, if a ray of light, after being reflected from a plane mirror, falls in the same plane upon another plane mirror, and is reflected therefrom, then the angle formed by the incident ray of the first mirror and the reflected ray of the second mirror, is equal to twice the angle formed by the surfaces of the mirrors themselves.

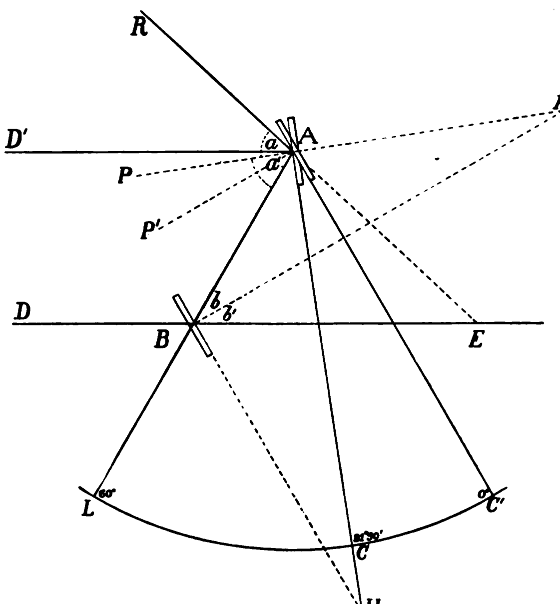


Fig. 2.

Figure 2 is a diagrammatic representation of the main parts of the Graphometer, A being the Index glass and B the Horizon glass as shown in Fig. 1. It is also supposed that from E an object at D is being sighted directly through the window and over or below the horizon glass B. The index arm is shown by the lines $A\ C$ and $A\ C^1$, the latter being its position when the Index Vernier is at zero of the graduated arc $C^1\ C\ L$. In this position the two mirrors are parallel to one another, and consequently the reflected image of an object at D^1 is seen in the mirror B in coincidence with the direct image at D. Considering the smallness of the instrument and the consequent nearness to each other of the mirrors A and B, the two parallel lines $A\ D^1$ and $B\ D$ may be, and usually are, taken to be one line, and the objects D and D^1, *when distant*, are practically one and the same. We shall therefore follow the general practice and consider that $B\ D$ and $A\ D^1$ are *parallel* and yet merge in the *same distant point* D, and also assume that our instrument is so adjusted that when the reflected image coincides with the direct one, the vernier zero likewise coincides with the zero of the graduated arc. The angle of inclination of the two mirrors, or the vertex angle $A\ E\ B$ will also naturally in such a case be $0°$. It is well, however, to note that if *near* objects are sighted and brought into coincidence, the vernier and the arc zeros will not coincide. The difference should be noted, and a plus or minus correction, the I. C., used in all observations of objects at such near distance.

We will now suppose that we are looking directly at an object beyond D, and that we wish to ascertain the angle subtended by it and another object beyond R. Having adjusted the mirror A by means of the index arm so that the reflected image of the second object in the mirror B is brought into coincidence with the first object viewed directly, then the angle read off on the graduated arc by the vernier is half the angle sought, that is

$$\text{Vertex Angle } R\ E\ D = 2 \text{ Angle } C\ A\ C^1$$
$$= 2 \text{ Angle } H.$$

Thus, in Fig. 2, the vernier gives a reading of $21° \ 30'$; the angle at E subtended by R and D is therefore $43°$.

That this is so will be evident from the following demonstration.

Let $P\ A\ F$ be perpendicular to the plane $A\ H$ of the mirror A,

and $B\ F$ be perpendicular to the plane $B\ H$ of the mirror B;

also let $P^1\ A$ be parallel to $B\ F$,

then $\quad$ Angle $P\ A\ P^1 =$ Angle F,

and $\quad$ Angle $P^1\ A\ B =$ Angle $A\ B\ F = b$.

Now $A\ D^1$ and $D\ E$ being parallel to each other,

$$\text{Angle } R\ A\ D^1 = \text{Angle } R\ E\ D,$$

and $\quad$ Angle $D^1\ A\ B =$ Angle $A\ B\ E = b + b^1$.

We have seen that the angle of incidence is always equal to the angle of reflection, therefore

$$\text{Angle } R\ A\ P = P\ A\ B, \text{ or } a = a^1,$$
$$\text{Angle } A\ B\ F = F\ B\ E, \text{ or } b = b^1,$$

and

$$\text{Angle } D^1\ A\ P^1 = P^1\ A\ B = b = b^1.$$

It is now evident that

$$\begin{aligned} R\ A\ D^1 &= R\ A\ B - D^1\ A\ B \\ &= (a + a^1) - (b + b^1) \\ &= 2\ a - 2b \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1.} \end{aligned}$$

$$\text{But } a = b + F$$
$$\text{and } 2\ a = 2\ b + 2\ F$$

therefore, by substituting in Eq. 1,

$$\begin{aligned} \text{Angle } R\ A\ D^1 &= 2\ b + 2\ F - 2b \\ &= 2\ F, \end{aligned}$$

$$\text{Consequently Angle } R\ E\ D = 2\ F = 2\ H \ldots\ldots\ldots\ldots \text{Eq. 2.}$$

The fact should not be lost sight of that the angle thus measured is the one having its vertex at E, and that the position of E will vary with the angle of inclination of the two mirrors, being behind the observer for very small angles, and very close to the instrument (or even within it) for large angles. It is therefore impossible to define at once its exact position, so that if it is necessary to know where a plumb-bob should be let fall, some computation of the length $A\ E$ must be made. Thus, if for a given instrument, we know the distance $A\ B$ and the angle $A\ B\ E$, we can compute $A\ E$, for

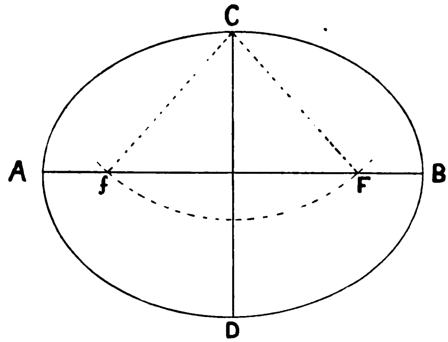
$$\text{Sin } A\ E\ B : A\ B :: \text{Sin } A\ B\ E : A\ E;$$

thus, if $A\ B$ be 1 inch and the angle $A\ B\ E$ be 60°, then for a vertex angle $A\ E\ B$ of 1° we should have $A\ E = 49.6$ inches, and for an angle of 40°, $A\ E = 1.35$ inches.

The various principles thus laid down apply equally to the Sextant, so that it is clear that both it and the Graphometer must be used with care when it is desired to determine the exact position of the vertex, and even then, it should not be considered as having been ascertained with absolute certainty. When measuring the angle subtended by two very distant objects, and when this angle is even a very small one, the position of E is of little moment and may be considered as being identical with that of the observer.

This peculiar feature of these instruments does not, however, detract from their value, and the Graphometer, with an Abney Level, would be found, by reason of their portability and other useful qualities, to render the greatest services to the Engineer engaged on Preliminary Surveys, Reconnaissances, etc., while scientific travellers would be enabled by their means to derive both pleasure and instruction from their use.

HOW TO DRAW AN ELLIPSE.



MANY DEVICES have been employed for drawing Ellipses, but we believe the simplest and most generally satisfactory Ellipsograph is one that is made with a pair of ordinary compasses with movable needle points in which a small hole is drilled close to their end.

The mode of procedure is as follows:—First draw the *major axis A B*, and the *minor axis C D* at right angles to, and cutting, the major axis, in the centre of its length, each one of the axes being of the length desired. Then take the compasses and pass a fine thread through each hole from the outside, and knot it on the inside, *the distance between the points being made equal to the major axis.* Then with the compasses opened to half the length of the major axis, place one point on the end *C* of the minor axis and describe an arc, cutting the major axis on each side of the minor axis in the points *F* and *f*; these points of intersection are the *foci.* Now take the compasses in the left hand and place one point on each of the foci, then with a pencil held in the right hand against the inner side of the loop formed by the thread, pass right round from one end *A* of the major axis, through *C* to its other end *B*, keeping the thread stretched all the while, when the half of the ellipse will be traced. Now reverse the compasses and trace in the same manner the other side *B D A*, thus completing the ellipse. The lines *C f* ane *C F* show the position of the thread when the pencil is at *C.*

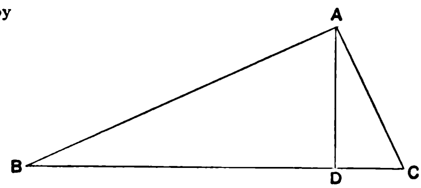
For ink work, special pen points are supplied with a small hook attached near the bottom of the inner nib, through which the thread slides as the drawing pen is being carried round. A small nick should be cut or filed in the pencil near its point, to prevent the thread from slipping on to the paper or up the pencil.

These drilled compass needle points can be procured from the Publishers of THE COMPASS, also pen points with hooks on them. It may sometimes be more convenient, instead of making a knot at each end of

the thread, to wind one end round the compass leg, and keep it firmly there with the fingers holding the compasses. By this means ellipses having varying axes may be more expeditiously drawn, as the tediousness of making the second knot exactly in the right place is avoided.

The above will be found a useful and ready method for drawing circles and circular surfaces, such as wheels, etc., in oblique positions, which otherwise is generally a tedious operation.

THE "PI" TRIANGLE.



THE ABOVE FIGURE represents a hard rubber or celluloid triangle so constructed, that by it certain properties of the circle may be at once solved, while owing to its being a right-angled triangle, it may be used in the usual way with the T. square for setting off perpendiculars.

Thus, let $B\ C =$ diameter of a circle,
then, $A\ D$ being perpendicular to $B\ C$,

$$B\ D = \frac{\text{Circumference}}{4} \text{ of the same circle,}$$

and $$A\ B = \text{Side of an equal square}$$

$$= \sqrt{\text{area of the same circle.}}$$

Let $$B\ C = 452 \text{ parts by any scale,}$$

then $$B\ D = \frac{452 \times \pi}{4} = 355$$

whence the circumference $= 355 \times 4 = 1420$,

and $$A\ B = \sqrt{452 \times 452 \times .7854}$$

or, from the properties of similar triangles,

$$A\ B = \sqrt{452 \times 355}$$

$$= \sqrt{160460} = 40045.57.....$$

Many cases of the usefulness of such a triangle will readily suggest themselves to the draughtsman without further recommendation on our part.

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. DECEMBER, 1, 1892. No. 5.

"SQUARING THE CIRCLE."

Industry, in its November issue, under the above heading, copies our article on the VALUE OF "PI" which appeared in our August number, and then continues:

> "The strangest thing we have ever seen in this connection was a brass plate prepared by Professor Harvey of Glasgow, so divided and fitted together that it could be arranged in a circle or a square. The plate was six inches in diameter and one quarter inch thick, and the joints were so carefully made that they were nearly invisible. It was based on the 3.2 theory above explained."

Are we to gather from this that *Industry* espouses the cause of the resuscitated 3.2 "Pi"? If so, we should be pleased to have particulars of the ground upon which they base their theory. The area of a 6 inch circle on the 3.2 π basis is 28.8 square inches, and on the 3.14159π basis 28.274 square inches, from which we have for the sides of equal squares 5.373 and 5.317 inches respectively, being a difference of 0.056 inches. Is it not possible that this was lost in the joints, or that the four sides of the square did not measure exactly 5.373 inches? We cry for *more light.*

ENGINEERING AND SURVEYING INSTRUMENTS. V.

Clinometers.

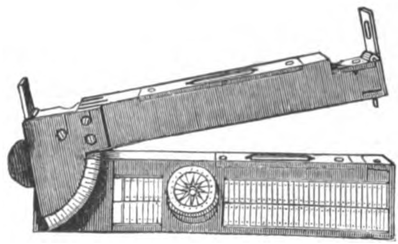


Fig. 1.

The Engineer or Architect has frequently to determine grades and to ascertain the amount or degree of slope of such as already exist. Various kinds of instruments are supplied to effect this, some being more useful or handy in certain cases, while others may be more applicable to other cases.

The Abney Reflecting Level and Clinometer, described in our November issue, is one of them. Fig. 1 is another useful Clinometer, which is also convenient for the pocket. It consists of two pieces of boxwood, 6 inches long, about $\frac{3}{8}$ inch thick and $\frac{3}{4}$ and $1\frac{1}{4}$ inch deep respectively, jointed at one end, and which, when fully opened out, may be used as an ordinary Foot Rule, being graduated to inches and eighths and also to inches and tenths. A small compass, graduated to divisions of 2 degrees each, is inserted in the front face of one of the pieces, whilst on the top face of each piece is a small spirit level. The ends of the upper surface of the instrument are provided with folding pin-hole and cross hair sights, so that the angle of elevation or depression of distant objects may be ascertained, the reading being taken from the edge of the lower level on a quadrant divided to single degrees, attached to the upper level. There are also two printed scales on the body of the instrument, one giving the number of degrees equivalent to slopes of 1 to 36 inches per yard, and the other giving the ratio of the vertical to the horizontal, such as a fall or a rise of *one* foot in 3 feet, 5 feet, etc.

When the Clinometer is used simply to determine a level surface, the two pieces are closed, and the motion of the upper bubble noted, but when it is used to ascertain the inclination of existing slopes, the two pieces are opened out, and if the surface upon which it is placed is the same as the inclined one, then the *upper* bubble is brought to the centre of its run, and the slope angle read off on the quadrant.

When, however, it is required to determine a non-existing grade, the Clinometer must be first placed on a level surface, ascertained to be such

by the bubble of the *under* level, then the upper piece is raised, the sight taken to any required given point in the grade, and the angle of inclination noted on the quadrant; or the upper piece is first raised to the required angle by means of the quadrant, when a distant point in the grade may be observed through the sights.

This Clinometer may also be used for determining the perpendicularity of walls, iron columns, etc., by opening out the levels to an angle of 90°, thus making a common leveling square. If the underside of the lower level is then set against the wall of a building or other required perpendicular surface, the upper level will at once indicate by its bubble whether it is perfectly vertical or not. It will also be found very useful for measuring the dip of mineral strata.

As the faces are of necessity all trued up, the instrument may even be used horizontally, if no other is at hand, for setting off or measuring angles on drawings.

Slopes or Grades are designated in different ways, but all give the proportion between their horizontal length and the difference of height of their extreme ends. The following methods of designation are more or less used.

1. Slope in Degrees, as a 5° Slope.
2. Rate per cent, or Ratio of *n* Units of vertical height to 100 units of horizontal distance, as 2 *per cent.*, 3 *per cent.*, etc., which may be 2 or3 feet, yards, metres, etc., rise in 100 feet, yards, metres, etc., of horizontal distance. This mode of designation is always used for metric measurements, as 2 *centimetres per metre*.
3. Ratio of Vertical Height to Horizontal Distance, as 1 *in* 60, 1 *in* 65, etc., which may be a rise of 1 foot, yard, metre, etc., in 60 or 65 feet, yards, metres, etc., of horizontal distance. This is the usual English method of designating slopes.

   Note. In No. 2, *the horizontal distance is a fixed quantity of* 100 *units, and the vertical varies, but in No.* 3, *the vertical is a fixed quantity of* 1 *unit, while the horizontal is a variable one.*
4. Inches per Yard, where the vertical height is given in inches, the horizontal distance being an invariable yard or 36 inches.
5. Feet per Mile, the vertical being a variable number of feet, and the horizontal being an invariable mile or 5280 feet. This method is only used for very slight inclinations, as rivers, canals, railroads, etc.
6. Ratio of base to perpendicular, as 2 *to* 1, 1½ *to* 1, etc. This mode is used to designate side slopes of embankments, cuttings and other similar works.

The following formulæ for reducing slopes in any one designation to

equivalent slopes in any other designation may sometimes be found useful.

To reduce Degrees to other designations.

$$\text{Tan } a \times 100 = \text{Rate per cent.}$$

$$\text{Cot } a = n \text{ Horizontal to 1 Vertical, (one in } n.)$$

$$\text{Tan } a \times 36 = \text{Inches per Yard}$$

$$\text{Tan } a \times 5280 = \text{Feet per Mile.}$$

To reduce Rate per cent. to other designations.

$$\frac{\text{Rate per Cent.}}{100} = \text{Tan } a$$

$$\frac{100}{\text{Rate per Cent.}} = n \text{ Horizontal to 1 Vertical, (one in } n.)$$

$$\frac{\text{Rate per Cent.} \times 36}{100} = \text{Inches per Yard}$$

$$\frac{\text{Rate per Cent} \times 5280}{100} = \text{Feet per Mile.}$$

To reduce Ratio of 1 *Vertical to n Horizontal* (one in n) *to other designations.*

$$n = \text{Cot } a$$

$$\frac{100}{n} = \text{Rate per Cent.}$$

$$\frac{36}{n} = \text{Inches per Yard.}$$

$$\frac{5280}{n} = \text{Feet per Mile.}$$

To reduce Inches per Yard to other designations.

$$\frac{\text{Inches per Yard}}{36} = \text{Tan } a$$

$$\frac{\text{Inches per Yard} \times 25}{9} = \text{Rate per Cent.}$$

$$\frac{36}{\text{Inches per Yard}} = n \text{ Horizontal to 1 Vertical, (one in } n.)$$

$$\frac{\text{Inches per Yard} \times 440'}{3} = \text{Feet per Mile.}$$

To reduce Feet per Mile to other designations.

$$\frac{\text{Feet per Mile}}{5280} = \text{Tan } a$$

$$\frac{\text{Feet per Mile} \times 5}{264} = \text{Rate per Cent.}$$

$$\frac{5280}{\text{Feet per Mile}} = n \text{ Horizontal to 1 Vertical, (one in } n.)$$

$$\frac{\text{Feet per Mile} \times 3}{440} = \text{Inches per Yard.}$$

In our next we shall give a complete table of Slopes with their equivalents in the various designations.

ADJUSTMENTS OF SURVEYING INSTRUMENTS. II.

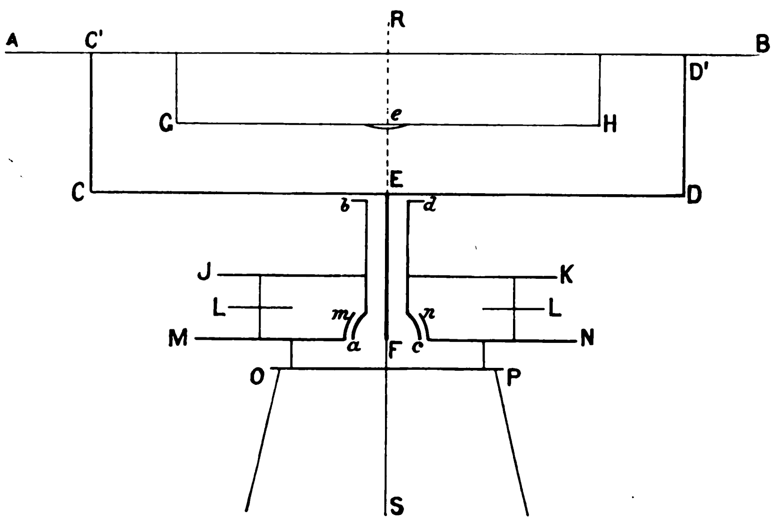


Fig. 1.

We Showed in the last issue the value of the method of *Reversion* for detecting errors in the Adjustments of Surveying Instruments, as by its means, the error not only becomes apparent, but its quantity is also determined.

Figure 1 is a Linear Diagram showing the *axes* of the principal movable and adjustable parts of an Engineer's Level, which require to be in perfect adjustment, such adjustments to be made in part by the maker, as a necessary quality of the construction, and in part by the operator.

In the above figure, the following parts are indicated, viz:—

$A\ B$ = Telescope axis and line of Sight or line of Collimation.
$C\ D$ = Level Bar.
$E\ F$ = Spindle or Inner Centre.
$G\ H$ = Level Tube, with
e = Centre of Bubble in the Centre of its run.
$J\ K$ = Upper Leveling Plate or Patent Leveling Arms.
L, L = Leveling Screws.
$M\ N$ = Tripod Plate.
$O\ P$ = Tripod Head.
$R\ S$ = Vertical Axis passing through the centre of the Spindle when the Instrument is perfectly adjusted, and the bubble is exactly in the centre of its run, or at the zero division of its graduations.
$a\ b$ and $c\ d$ = the outer Centre or Sleeve, with half ball, forming the half ball joint with
$m\ n$ = Ball Sockets,
$\left.\begin{matrix} C\ C^1 \\ D\ D^1 \end{matrix}\right\}$ = Wyes.

It will be at once seen that the lines $A\ B$ and $R\ S$ are in principle the same as the lines $A\ B$ and $C\ D$ of Figs. 1, 2 and 3 in our former article, and that upon them mainly depend the adjustments of the Level.

We will, however, examine these various parts of the instrument more closely, and then see how the adjustments are effected.

We have shown that our starting point or the basis of all surveying and astronomical operations is that earth's radius upon which we are for the time being located; and all observations are in fact reduced to this line, and to its initial point, the earth's centre. This line, which is *per se* a true vertical, is represented by the line $R\ S$, passing through the spindle of the Level, while the point of the earth's circumference which it cuts will be indicated by the plumb-bob, hanging from the bottom F of the spindle. To obtain a perfectly *horizontal* line, the lines $J\ K$, $C\ D$, $G\ H$ and $A\ B$ should now be perfectly parallel to one another and exactly perpendicular to $R\ S$. To ascertain that this is exactly so, we have recourse to the level tube $G\ H$ with its bubble e, as by this alone, and the principle of reversions, can we verify the verticality and the horizontality of the different lines.

The line $M\ N$ represents the tripod plate of the instrument, which is screwed on to the tripod head $O\ P$. The instrument is then set up on its legs so that $O\ P$ may be as nearly horizontal as can be, judging from general appearances. In the process of *construction* the outer centre or sleeve $a\ b$ and $c\ d$ is made perfectly concentric with the axis of the spindle $E\ F$, the upper surfaces of the collar b and d upon which the level bar

rests, being also *constructed* perfectly perpendicular to the axis of the spindle to which the level bar *C D* is firmly attached. We say the axis of the spindle, because it is always made slightly conical so as to gently bear upon the inner surface of the sleeve and yet be capable of easy revolving motion.

If now the axis of the level tube *G H* is parallel to the level bar *C D*, then when *G H* is horizontal, as shown by the bubble *e* being exactly in the centre of its run, *G H* and *C D* will both be perfectly perpendicular to *E F* and to *R S*. If, however, *G H* and *C D* are not parallel to one another, then. when the bubble *e* is in the centre of its run, and *G H* is consequently horizontal, *C D* will not be horizontal, and naturally the axis *E F* of the spindle is not coincident with *R S*, the true vertical, as was shown in our last number.

By the same process of reasoning, if the axis *A B* of the telescope is parallel to the level bar and to the level tube, then, when *AB* is horizontal, as shown by the bubble *e* being exactly in the centre of its run or at zero, *A B* will be perpendicular to *E F* and to *R S*. But if, by reason of one of the wyes C C^1 or D D^1 being a little longer than the other, *AB* is not parallel to *G H*, then, when the bubble *e* is in the centre of its run, and the level tube consequently horizontal, the telescope axis will not be horizontal, and will naturally not be perpendicular to *E F* and *R S*.

But the case may arise in which the telescope axis *A B* is parallel to the level bar *C D*, but yet not parallel to the level tube *G H*, In such a case it clearly follows that bringing the bubble to the centre of its run at *e* does not make the telescope axis either horizontal or perpendicular to *R S*, the basis of all leveling operations.

We have, in a Level, therefore, as a basis, the imaginary vertical line *R S*; and by *construction*, when the spindle axis *E F* coincides with *R S*, then the level bar *C D* is horizontal, and also perpendicular to *R S*. The wyes supporting the telescope are made adjustable, as are also the ends *G* and *H* of the level tube, to allow of these being made parallel to each other and to the level bar, so that when the bubble is in the centre of its run at *e*, *A B*, *C D* and *G H* are all perpendicular to *E F* and *R S*, and the telescope axis *A B* is consequently *horizontal* in all positions of the horizontal plane to which it may be turned round.

Such are in theory the requirements of a perfectly adjusted instrument. We shall see further on how they are carried out in practice. We must, however, examine first the telescope and see what is required of it.

(*To be continued.*)

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

LIGHT: ITS REFLECTION AND REFRACTION. V.

IN OUR LAST we explained the principles underlying the construction of the Graphometer, and by anology, the Sextant. We shall now give a few examples of the many problems for whose solution it is specially suited, as stated in our October number.

It should be distinctly noted that the following examples are given with strict reference to the GRAPHOMETER. in which the divisions on the arc are figured according to their *real value* thus indicating the angle of inclination of the two mirrors, which is only *half the angular distance* between two objects of which one is viewed directly and the other by reflection.

1. *To set out a perpendicular on a given line A B from a given point B.*

Set the zero of the vernier to 45°, so that the angle formed by the incident ray of the first mirror and the reflected ray of the second mirror shall be equal to 90 degrees, = angle *A B C*. Hold the instrument over the given point *B*, and look through the window, and over or below the horizon glass at another point or rod at *A* on the given line. Now send

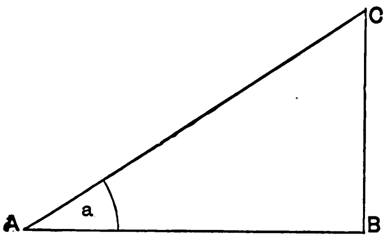


Fig. 1.

out a rodman towards C, and by signs direct him to hold his rod in such place and position, that it may be seen reflected in the horizon glass in coincidence with the rod at A seen directly through the window. $B\ C$ will then be the required line perpendicular to $A\ B$.

2. *To measure the distance $A\ B$, the point A being inaccessible.*

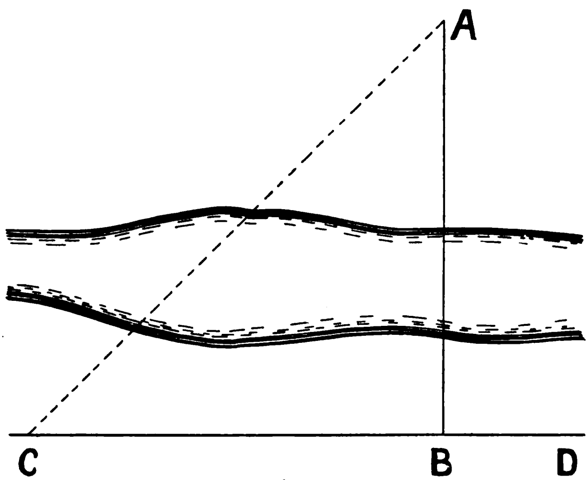


Fig. 2.

With the vernier zero of the instrument at 45 degrees, set off a perpendicular $B\ C$, then with the vernier set to $22\frac{1}{2}$ degrees, proceed towards C until a point C is found from which A and B are seen to coincide, the one by direct vision and the other by reflection. $B\,C$ is then equal to $A\ B$.

It may sometimes be more convenient to set a rod at D, perpendicular to B on the line $A\ B$, as described, then to walk towards C, keeping the rod D continually covered by B, until the point C is reached.

Other angles may also be taken instead of $22\frac{1}{2}$ degrees, thus

With angle	$= 28^\circ\ 09'$	$A\ B$	$=$	$1\frac{1}{2}$	$B\ C$
" "	$= 31^\circ\ 43'$	"	$=$	2	"
" "	$= 34^\circ\ 06'$	"	$=$	$2\frac{1}{2}$	"
" "	$= 35^\circ\ 47'$	"	$=$	3	"
" "	$= 37^\circ\ 59'$	"	$=$	4	"

If it should be impossible by reason of obstructions to set off $B\ C$ perpendicular to $A\ B$, take for B any other suitable angle and set off a line cutting $A\ B$ in B, and making with it the angle selected. Now set the vernier zero to $90^\circ - \frac{1}{2}\ B$ and proceed as before until both A and B are seen to coincide. $B\ C$ and $A\ B$ will again be equal to each other.

3. *To measure the distance between A and B, both of these points being inaccessible.*

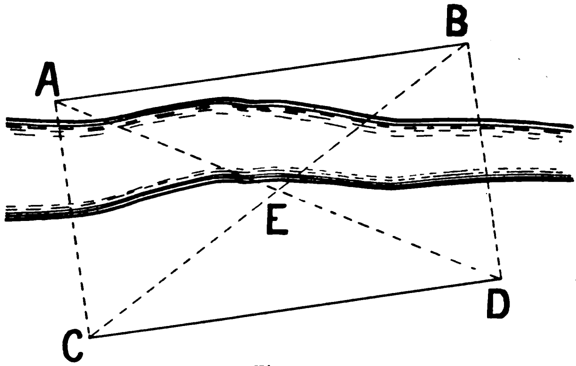


Fig. 3.

Select any suitable position E and measure the angle $A\ E\ B$. Now set the index of the Graphometer to half that angle, that is, to a quarter of the real value of the angle AEB, and proceed towards C, until at the point C the points A and B are seen to coincide, the one viewed directly and the other by reflection. $A\ E$ will then be equal to $C\ E$, seeing that

$$A\ E\ B = 180^\circ - A\ E\ C$$

and $$E\ A\ C + E\ C\ A = 180^\circ - A\ E\ C;$$

but by construction $$E\ C\ A = \tfrac{1}{2}\ A\ E\ B$$

therefore $$E\ A\ C = \tfrac{1}{2}\ A\ E\ B = E\ C\ A,$$

consequently $$A\ E = C\ E.$$

Proceed in the same manner to find the point D, then will $C\ D = A\ B$.

4. *To measure the height A B.*

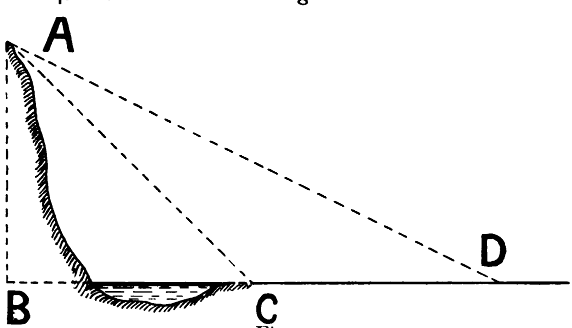


Fig. 4.

Set the index to 45° and holding the instrument in a vertical position, find a point C, at which B, horizontal with the eye, and A are seen to coincide. Then are $B\ C$ and $A\ B$ equal to each other. This of course supposes that B is accessible. As in Example 2, the instrument may be set to other angles than 45°. It may be however found to be impossible to make use of the angles there given, in which case, take *any* convenient point C and measure the angle $A\ C\ B$, which is twice that shown by the index vernier, calculating the height $A\ B$ by the formula

$$A\ B = B\ C \tan A\ C\ B.$$

5. *To measure the height A B when the point B is inaccessible.*

At C measure the angle $A\ C\ B$, then proceed to any other conven-

ient point D in line with B and C, and measure the angle $A\ D\ C$, also measuring the distance $C\ D$, then

$$A\ B = \frac{C\ D}{\text{Cot}\ A\ D\ B - \text{Cot}\ A\ C\ B}$$

Or find a point C at which $A\ C\ B = 45°$, and a point D at which $A\ D\ B = 26°\ 34'$, then is $C\ D = A\ B$. In place of these angles. C may be made $26°\ 34'$ and $D = 18°\ 26'$, in which case also $C\ D = A\ B$. Other suitable combinations can easily be found.

It should be noted that in examples 4 and 5, where trigonometrical computations have to be made, the *real angle* must always be taken, which is *twice* that shown by the index vernier.

6. *To ascertain Altitudes with the Artificial Horizon.*

In THE COMPASS for August we incidentally referred to the use of the Artificial Horizon in connection with the Sextant for the purpose of observing Altitudes.

Let it be required to ascertain the altitude of an object beyond R in the direction $E\ R$ that is, the value of the angle $R\ E\ H$, in which $E\ H$ is the true horizon. After setting up the artificial horizon $t\ t^1$ on the ground, the observer should so place himself at E that he sees clearly the reflection of the object R in the horizon at D, then taking the Graphometer in the left hand, look through the window at this reflection *directly*, whilst with the right hand he turns the index round until the image of R is seen by reflection in the horizon glass to coincide with D in the artificial horizon. The angle $A\ C\ B$, *read off by the vernier*, will then be equal to the angle $R\ E\ H$, or half the observed angle $R\ E\ D$.

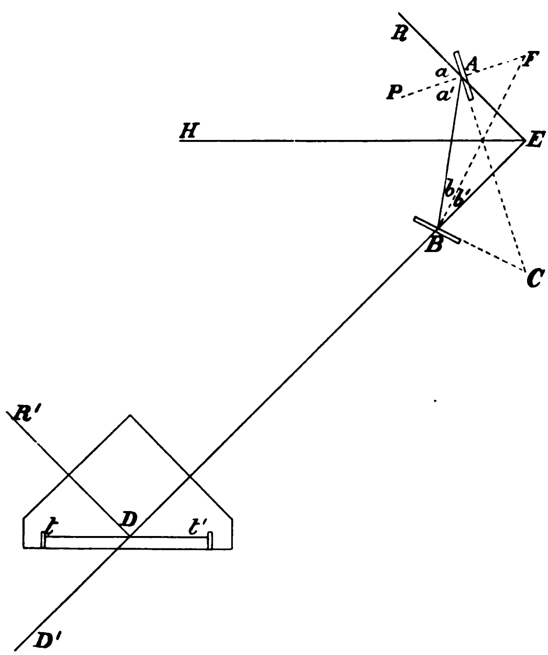


Fig. 6.

It is pre-supposed, as was stated in our last number, that the rays of light $R\ E$ and R^1 D, (equivalent to $D^1\ A$ and $D\ B$ in Fig. 2, page 60), from the object are parallel, which is practically the case for very distant objects. If, however, the object whose altitude is sought is near, then $R\ E$ and $R^1\ D$ will clearly not be parallel, and a correction must consequently be made, namely, half the angle between $R^1\ D$ and $R\ E$ must be added to the angle $A\,C\,B$ read off by the vernier.

In conclusion, it may be stated that the chief value of the graphometer, (as well as of the Sextant), is its great portability, and the fact that it requires no tripod or other fixed support; it may be used when walking, on horseback or on the sea. It can also be used for ascertaining the unknown position of an object from two angles, measured to three points or objects whose relative positions are previously known,—commonly called the "three-point" problem.

A NEW COMPOUND TRIANGLE.

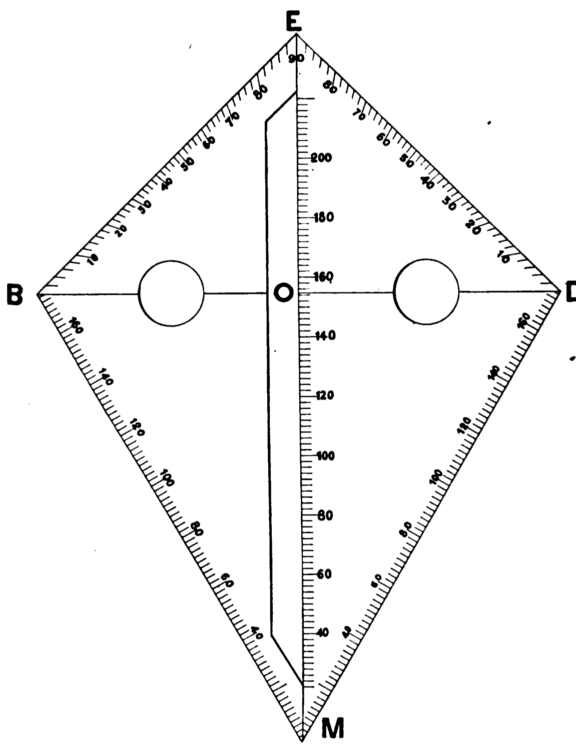


Fig. 1.

THE ABOVE FIGURE shows a new COMPOUND TRIANGLE which, even in its simplest form, will he found a very useful tool for the draughtsman, as by combining in its construction several simple triangles, he can with it and an ordinary straightedge, set off angles of 15, 30, 45, 60, 75, 90, 105, 120, 135 and 150 degrees. It also enables him to set off at once perpendiculars which shall *not only touch*, but *cut* any given straight line, that is, meet it on both sides.

By means of the graduated scales, a radius may be *drawn* to any circular curve, or the centre of any circle may be easily found, whilst the diameter of any circle or the radius of any circular curve may also be *calculated* with it.

These Compound Triangles are made in Black Rubber, without any graduated scales, for use in the draughting room as ordinary triangles; and also in Celluloid, with the various graduated scales, as shown in the figure, being then also called CURVE RADIATORS AND PROTRACTORS.

The following are some of the various methods of using this new triangle.

1. *To draw a perpendicular to a line that will not only touch it, but will cut it.*

Place the triangle on the given line in such a manner that the line *B D* may coincide with it, then *E M* is perpendicular to, and cuts the given line. In the same way perpendiculars or radii may be drawn from railway and other curves. This line *B D* is traced on the Black Rubber Triangles.

2. *To plot Angles.*

The upper angle of the instrument, or *B E D* gives at once 90°, the angles *M E D* and *M E B* each 45°, while the lower angle *M* gives at once 60° and 30°. By means of a straight edge, the following may also be very easily plotted, namely 15°, 75°, 105°, 120°, 135° and 150°. Other angles may be plotted by placing the triangle so that the line *B D* shall coincide with the line upon which the desired angle is to be constructed, and so that the point *O* of intersection of *E M* and *B D* shall be the apex of the same, then with the proctractor scales *B E* and *E D* lay of the required angle.

3. *To draw a radius to any circular curve.*

In the case of curves of small radius, lay the triangle on the curve so that 60, 80 or 100 of each of the side scales *B M* and *D M* shall cut the curve, then *E M* is a radius to the curve. In the case of curves of large radius it will be well to make 150 or 160 of each of the side scales coincide with the curve.

4. *To find the centre of any circle.*

For circles of not more than 8 inches radius, it suffices to place the

triangle so that the circumference will cut the *three scales* in exactly the same place. thus the circumference of a circle 16 inches diameter will cut the three scales at the division 160, and the point *M* will be the centre of the circle. (Note: the scales are all divided to 20 parts to an inch.)

For circles of greater diameter, set the triangle so that the circumference cuts each of the side scales at the same division, say 150, then draw a radial line. Repeat this in another position of the circumference, when the intersection of the two radial lines will be the centre of the circle. The centre of curvature of any circular curve may be obtained in the same manner.

5. *To calculate the diameter of any circle or the radius of any circular curve.*

Set the triangle so that 100 of each side scale coincides with the circumference of the circle, then note the reading of the centre scale where the circumference intersects it, and deduct 86.6 from it. Call the remainder x, then the following formula will give the diameter in inches.

$$\text{Diameter} = \left(\frac{2500}{x} + x\right) \div 20$$

When the radius of curvature is more than 8 inches, let 160 of the side scales coincide with the circumference or curve, and deduct 138.56 from the reading of the centre scale, then

$$\text{Diameter} = \left(\frac{6400}{x} + x\right) \div 20$$

An interesting peculiarity of this Compound Triangle is that it gives *very nearly correctly* in a graphic manner the circumference of a circle and also the side of a square having an area equal to that of a given circle.

Thus, in Fig. 2,

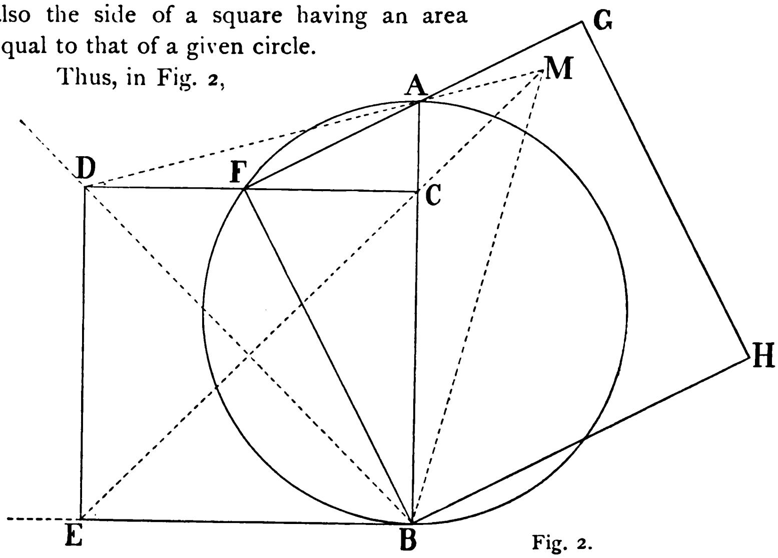


Fig. 2.

et $AB =$ Diameter of the circle FAB,

then $BC = \frac{1}{4}$ Circumference, or

$$BC + CD + DE + EB = \text{Circumference},$$

and $FB^2 =$ Area of the Circle.

These are correct to 4 per mille.

In the above figure, $DMBED$ represents the Compound Triangle, and AB, perpendicular to the side or base BE, is the diameter of the circle. This can, by means of the T Square, or by using a Parallel Rule, be made any length. Now draw with the Triangle DM and BM, and from the point of intersection M, draw MCE, then draw from E the perpendicular ED, and from the point of intersection D, the line DC, parallel to BE. Then is, as stated

$$BC = \tfrac{1}{4} \text{ Circumference}$$

and $FB^2 =$ Area of the Circle whose diameter is AB.

The Circumference and Area as thus found are but 4 per mille too great, which frequently in such drawings would be of but little moment. For perfectly correct results, the "*PI*" Triangle, described in our last, should be used in a similar manner.

NEW BOOKS.

THE THEORY AND PRACTICE OF SURVEYING; designed for the use of Surveyors and Engineers generally, but especially for the use of Students in Engineering. By J. B. Johnson, C. E. John Wiley & Sons, New York, 1892. 8 vo. cloth, 754 pages, with numerous illustrations and tables. Price $4.00.

This well-known and deservedly popular work, which has reached a tenth and enlarged edition, is divided into two parts, the first one treating of the construction, adjustment, use and care of instruments used in surveying, either in the field or the office. Part II includes descriptions of the theory and practice of surveying methods in the several departments of Land, Topographical, Railroad, Hydrographical, Mining, City and Geodetic Surveying; Surveys for the Measurement of Volumes, etc.

The plan adopted by the author is that of presenting the various subjects concisely and scientifically, so that the student may know the "why" and the "wherefore" of every step he takes, whether in the adjustment of his instruments, the actual work in the field, or the necessary subsequent computations.

Chapter VII on Land Surveying, will be found especially valuable, as it describes very clearly and fully the United States System of laying

out the Public lands, and also gives the principles and laws bearing on the Resurvey of Private Lands, based upon a careful digest of a large number of judicial decisions, which should govern the Surveyor in his actions.

In one of the Appendices will also be found the latest instructions on the triangulation, precise leveling, topographic and hydrographic surveys of the Mississippi River, issued by the Mississippi River Commission to its field parties. As they embody the experience of nearly forty years of such work, they will be found to well repay careful consideration, representing, as they do, the latest and best methods of conducting such surveys.

A Treatise on Highway Construction; designed as a Text Book and Work of Reference for all who may be engaged in the Location, Construction or Maintenance of Roads, Streets and Pavements, by Austin T. Byrne, C. E. John Wiley & Sons, New York, 1892. 8 vo. cloth, 686 pages, 90 tables and 249 illustrations. Price $5.00.

The appearance of this book is most opportune, especially when considered in connection with the efforts being made at the present time to induce the Senate and House of Representatives to establish a Road Department in Washington, similar to the Agricultural Department, whose creation has been so beneficial.

It may be taken as a very true maxim that the roads of a country are a faithful index of its moral and material prosperity. That good roads are a necessity, none will deny, and that such are painfully (both for man and beast) lacking in many States of the Union, is well known; but yet it must in common fairness be allowed that there are many difficulties in the way of the establishment of such systems as are met with in France, England, Belgium and other countries of the Old World. Here, distances between manufacturing and commercial centres are enormous, and the population and consequent means of maintenance out of all proportion to the needs of the commercial and agricultural community.

The careful study of this work will well repay all those who are connected with the civil administration of the affairs of this vast nation, as well as those personally interested in the management of large estates, from the development of which they seek to obtain the most profitable returns.

The book is methodical in arrangement, clear and concise in language, well illustrated, and readable from a typographical point of view, and we heartily commend it to all who have at heart the welfare of this great and glorious country.

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. JANUARY 1, 1893. No. 6.

THE EIDOGRAPH.

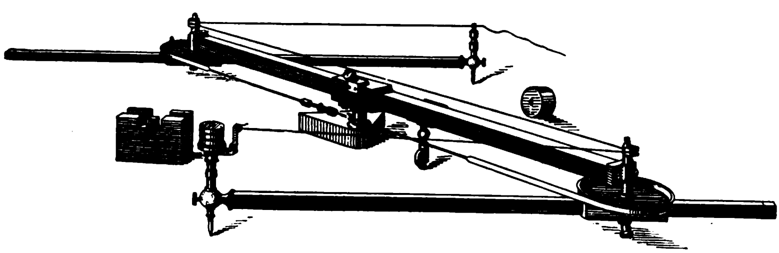


Fig. 1.

THE EIDOGRAPH is an instrument, invented by Professor Willis in 1821, for making copies of drawings on an enlarged or reduced scale. Its construction is based upon the theorem (Euclid VI., prop. 6) to which we have already referred in our articles on the Pantograph, but it is, owing to the almost entire absence of friction in the moving parts, a more sensitive, and consequently, more manageable and reliable instrument than the Pantograph.

The Eidograph, as represented in Fig. 1, consists of a main or centre square beam, which slides in a socket, said socket revolving horizontally upon a pin projecting from a substantial weight, which serves as a standard for the support of the whole instrument. This pin, which is accurately turned and fitted to its bearing in the socket, is the fulcrum of the instrument, and the weight has on its under surface 3 or 4 fine needle points, so that its position on the drawing board may be steadily maintained during the operations of enlarging or reducing. The main beam can be clamped in the socket in any required position, according to the scale of the drawing to which the instrument is set. At each end of this beam is another socket, in which revolves a well-fitting pin, which serves as the axis of rotation of a disc wheel, grooved on its circumference, and having attached to its under surface a sleeve or box. An arm passes through each of these boxes, one end of which is adapted to receive an interchangeable pencil or tracing point; these arms can also be clamped in their respective boxes in any desired position.

The two disc wheels are connected with one another by a steel band, attached to their circumference in the groove, so that motion given to the one transmits similar and simultaneous motion to the other. These bands are adjustable on both sides of the centre beam, so that a suitable degree of tension may be given them, and that the arms may be made perfectly parallel to each other. To preserve this parallelism throughout their various movements around their respective axes, it is obvious that the discs must be exactly of the same size, and also perfectly centred. If motion be then given to the tracer at the end of one arm, similar and equal or proportionate motion is transmitted to the pencil at the end of the other arm. When it is desired that a certain fixed ratio shall exist between the motion of the tracer and pencil points, the centre beam and the arms must be so adjusted in their sockets that this same ratio shall exist between the two sections of the centre beam, and also between the distances of the tracing and pencil points from their axes of revolution.

In order to facilitate the accurate setting of the centre beam and the two arms to the desired ratio, the total length of each of these pieces is divided into 200 *equal parts*, each one of which is further subdivided by means of a vernier into tenths. These graduations are not, however, carried over the entire length of the bars, as divisions from 0 to 100, reading with the vernier to 1000, are practically all that are needed for the great number of proportions to which the instrument is capable of being set. Thus, suppose we wish to enlarge a drawing in the proportion of 3 to 5. This ratio is clearly equivalent to 75 to 125, and $75 + 125 = 200$, so that the fulcrum must be placed at a distance of 75 parts from one of its end sockets and 125 parts from the other end socket. Likewise, the

tracer should be 75 parts from its axis, and the pencil point 125 parts from its axis, as shown in Fig. 2.

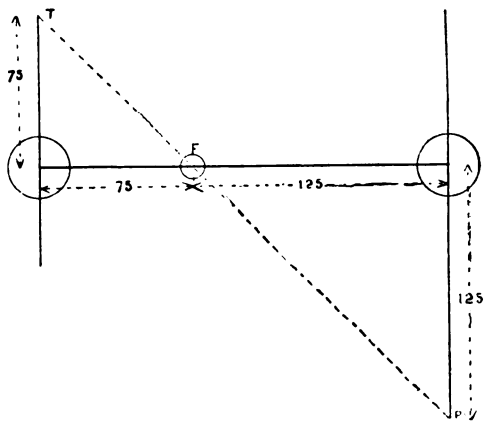


Fig. 2.

The setting of the beam and the arms for different ratios is obtained from a table placed in the lid of the box which contains the instrument, or else from the following simple formula,

$$\text{Setting} = \frac{200 \times y}{x + y}$$

in which x is the greater term, and y the lesser term of the ratio. Thus, for the ratio of 2 to 5 we have

$$\text{Setting} = \frac{200 \times 2}{5 + 2} = 57.1$$

the whole number 57 being the division on the beam and arms, while the decimal 0.1 is set by their respective verniers.

In some of the older instruments the figuring of the beam and arms commences at the sockets with zero and proceeds toward their ends up to 100. We consider this method objectionable, as the setting does not of itself show the ratio to which the instrument has been adjusted, whereas with the method we have adopted it does; thus in the example given,

$$2 : 5 :: 57.1 : 200—57.1$$

that is

$$2 : 5 :: 51.1 : 142.9.$$

The formula for the older style is

$$\text{Setting} = \frac{100\,(x—y)}{x + y}$$

by which the setting for the ratio of 2 to 5 is 42.9, which bears no propor-

tion whatever to the total length of the beam and arms and to the given ratio.

Minor details concerning the construction of the Eidograph are.

1st. A round weight with a square hole in it for placing on the tracing arm, to balance it when the instrument is set for reductions to a large scale.

2nd. A detachable caster or wheel support, which can be placed under the centre beam, as shown in Fig. 1, when the scale of the drawing necessitates the fulcrum being considerably beyond the centre of the beam, thus reducing the friction on the fulcrum by balancing the beam and arms. Sometimes a large weight is placed upon the centre beam for the same purpose; the caster support is however to be preferred.

3rd. The pencil and tracing points are, as already stated, interchangeable. As thus the lesser term of a ratio can always be set on the same arm, this arm is made but a little more than half the length of the other one, upon which the greater term of the ratio is set.

4th. The pencil point may be raised from the surface of the paper, as in the pantograph, from the tracing point, by means of a lever and cord, when desired.

As in the Pantograph, the Fulcrum, Pencil and Tracing points should all be in a straight line, when these various parts are correctly set. It is, however, necessary to examine from time to time the instrument to see if it is in perfect adjustment, as if the tension of one of the steel bands differs from that of the other band, the movement imparted to one arm will not be simultaneously transmitted to the other arm; or, the bands may be so adjusted that the two arms are not perfectly parallel. To determine if any error exists, make the zero of the three verniers coincide with the 100th division of the centre beam and arms, then make a mark on the drawing board with the pencil and tracing points, the centre beam and arms being maintained absolutely in the same position while each of these marks is being made. Now turn the centre beam half way round and place the tracer over the pencil mark, then, if the pencil point coincides with the mark made by the tracing point, the instrument is in adjustment, If, however, they do not coincide, the amount of divergence must be noted. and *half* of this difference must be corrected by means of the adjusting screws on each of the bands. It will be seen that this is the method of adjustment by means of *Reversion*, to which we have lately devoted some space with special reference to Surveying Instruments.

Very complex reductions or enlargements may be made with the Eidograph, precisely as with a fully divided Pantograph, and with the Universal Proportional Dividers. This method of division into equal parts is in fact the only rational mode of graduating such instruments.

Suppose for instance, we have a plan drawn to a metric scale of 1 millimetre = 1 metre, and that we wish to reproduce it to a scale of 1 square inch = 1 square chain: we reduce both these scales to ratios of a common denomination, thus

$1^m/_m$ = 1 metre is equivalent to 1 : 1000.

1 square inch = 1 square chain is equivalent to a lineal scale of

80 inches = 1 mile, which is the same as 1 : 792. The reproduction of our plan must therefore be made to the proportion of 792 : 1000. From the formula given, we have

$$\text{Setting} = \frac{200 \times 792}{1000 + 792} = 88.4$$

88 being determined by the graduations on the beam and arms, and 0.4 by the verniers.

We can also, if we wish, reproduce a drawing so that the area of the original and the copy may bear any desired proportion to each other; thus suppose for a special purpose we wish to reduce the *area* of a certain plane surface from 5 to 3. yet maintaining exactly the same form of outline, we have

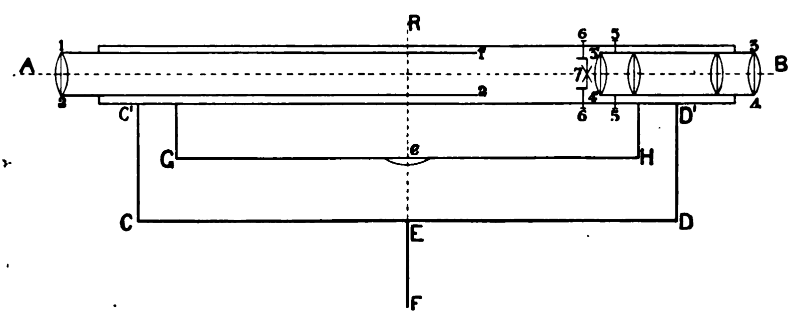
$$\text{Setting} = \frac{200 \times \sqrt{3}}{\sqrt{5} + \sqrt{3}} = 87.3.$$

so that the area of any surface reproduced with the beam and arms set at 87.3 will be to the original as 3 is to 5.

Other and similar uses of the Eidograph will readily present themselves, and a little practice will suffice to convince even the most sceptical of the simplicity and advantage of this method of graduation.

ADJUSTMENTS OF SURVEYING INSTRUMENTS. III.

WE EXPLAINED in our last issue the theory of the chief adjustments of a Level, and now proceed to the consideration of its telescope.



In the above figure let

$\left.\begin{array}{l}1, 1^1\\2, 2^1\end{array}\right\}$ = Objective Tube,

1, 2 = Objective Lens,

$\left.\begin{array}{l}3, 3^1\\4, 4^1\end{array}\right\}$ = Eye Piece Tube,

3, 4 = Eye Lens,

5, 5 = Screws for adjusting Eye Piece Tube,

6, 6 = Screws for adjusting Cross Hairs (*See Fig.* 1, *page* 86, *Vol. I.*),

7 = Intersection of the Cross Hairs.

The letters refer to the same parts shown in the figure given in our last article.

The telescope consists of a main tube, in and out of each end of which a secondary tube slides. Lenses are fixed in these secondary tubes, from which they take their names of Objective Tube and Eye Piece Tube.

It is essential in a good Telescope that the optical axis of each of these lenses shall coincide and form one unbroken straight line which shall coincide with the telescope axis, and that this line, in the case of a Level, be parallel to the axis of the level tube, that is A B and G H should be parallel to each other.

It is further essential that the glasses of which these lenses are composed be perpendicular to their common optical axis, that is, Nos. 1–2, 3–4, 3^1–4^1, etc., must all be perpendicular to the optical axis A B. This is a natural consequence of the first condition.

In surveying it is necessary that the operator be able to direct the optical axis as well as the axis of revolution of his telescope with great precision upon a special *point* of the object he is viewing, or upon a certain given graduation of a staff held up at some distance before him. To enable him to do this, two fine hairs or wires are placed in the main tube of the telescope at a point which may be made to be by adjustment of the objective and eye-piece, the point of their common focus. These hairs are placed at right angles to each other and to the telescope axis, and their point of intersection No. 7, can be adjusted and brought by means of the four screws No. 6, to coincide with the optical axis, that is, the point No. 7 must be cut by the line A B. The imaginary line passing through the optical axes of the different lenses and through the point of intersection of these cross hairs is called the *line of sight* or the *line of collimation.* We have therefore

1st. *The telescope axis of revolution,* which should be a perfectly straight line passing through the centre of the telescope and of its collars, throughout its whole length.

2nd. *The optical axis,* which should be coincident with the telescope

axis, to whatever extent the objective and eye-piece tubes may be drawn out or pushed in.

3rd. The *line of sight* or *line of collimation*, passing through the intersection of the cross hairs, and which should coincide with the two former.

In a perfectly adjusted instrument these three lines will coincide with one another and all correspond to the line *A B*.

It is evident that should the objective tube not slide out perfectly parallel to the telescope main tube, the objective lens would not in all positions of its course be perpendicular either to the telescope axis or to the line of collimation, and consequently the rays of light proceeding from an object would not converge at the point of intersection of the cross hairs, that is the common focus of the objective and eye-piece, but on one side of it, and if the telescope is revolved in its wyes, the image formed by the objective will appear to move around the intersection of the cross hairs.

In some makes of instruments, the sliding objective tube is adjustable at its inner end 1^1–2^1, but in the Levels and Transits which we have described in previous numbers of THE COMPASS, the accuracy of this sliding motion is secured in the course of construction and requires no further attention on the part of the Engineer or Surveyor. This method of construction possesses many advantages over the adjustable one.

The eye-piece tube is adjustable by means of the screws 4–5, so that it may be centered, that is, its optical axis may be made to coincide with the telescope axis and with the point of intersection of the cross hairs.

To insure the telescope axis of revolution being coincident with its optical axis in all positions of the telescope, it is necessary that the two collars encircling it, and which rest and revolve in the wyes, should be each absolutely of the same diameter and also be perfectly concentric with the line *A B*.

To sum up—we may say that in a perfectly adjusted and correctly constructed Level, the various horizontal lines shown in our figures should be parallel to one another, while all the vertical lines should be perfectly perpendicular to the former. That these conditions are carried out, depends in many points upon the maker, while the Surveyor has to undertake the others himself, and that frequently.

In our next we shall examine in detail those points which require the Surveyor's or Engineer's attention, and see how he is able to obtain the conditions necessary to the perfect adjustment of his instrument.

(*To be continued.*)

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

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K. & E. POCKET FOLDING RULES.

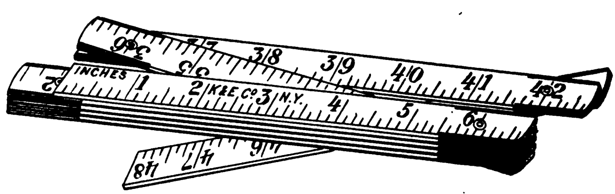


Fig. 1.

ALTHOUGH A STEEL Tape in German Silver Case, with spring and stop, is undoubtedly the most convenient kind of measure for carrying in the pocket, yet it has its disadvantages, the chief being that both ends of the object to be measured require to be easily accessible, and the tape should, unless tightly stretched, be supported along its whole length, to prevent sag and consequent incorrect measurements. When such cannot be, then recourse must be had to some other kind of instrument.

The K. & E. Pocket Folding Rules with *spring joints,* of which we give a representation in Fig. 1, overcome the above objections, and fill a long felt want. These Rules are made of wood, prepared by a peculiar process, so that shrinkage is entirely prevented. The wood is cut into thin strips about 7 inches long, jointed every six inches, forming a Rule from 2 to 8 feet in length, the thickness of a 4 foot Rule being less than $\frac{7}{8}$th inches. As the divisions are made mechanically, they may be fully relied on, and the wood being very thin, they can be brought close to the object to be measured; the divisions over the joints are also perfectly legible. When this Rule is fully opened out, it is held in a straight line by the spring joints so that it may be used for measuring vertically or horizontally to an otherwise inaccessible point, or to an object when the intervening space is not in the same plane. As stated, they are made in various lengths, and are marked on both sides in inches and sixteenths. The 4 foot Rule is also made with metrical divisions on one side and inches on the other.

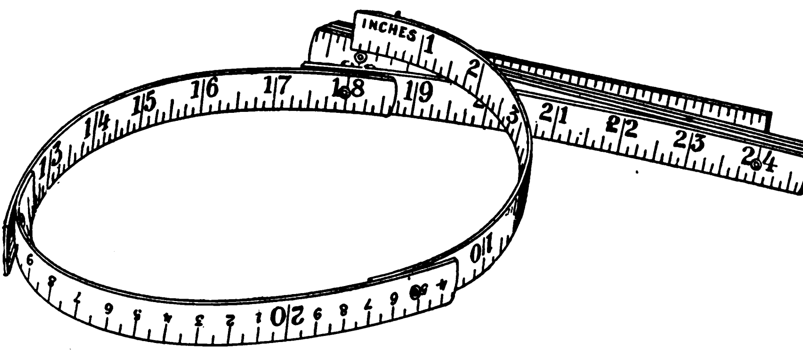


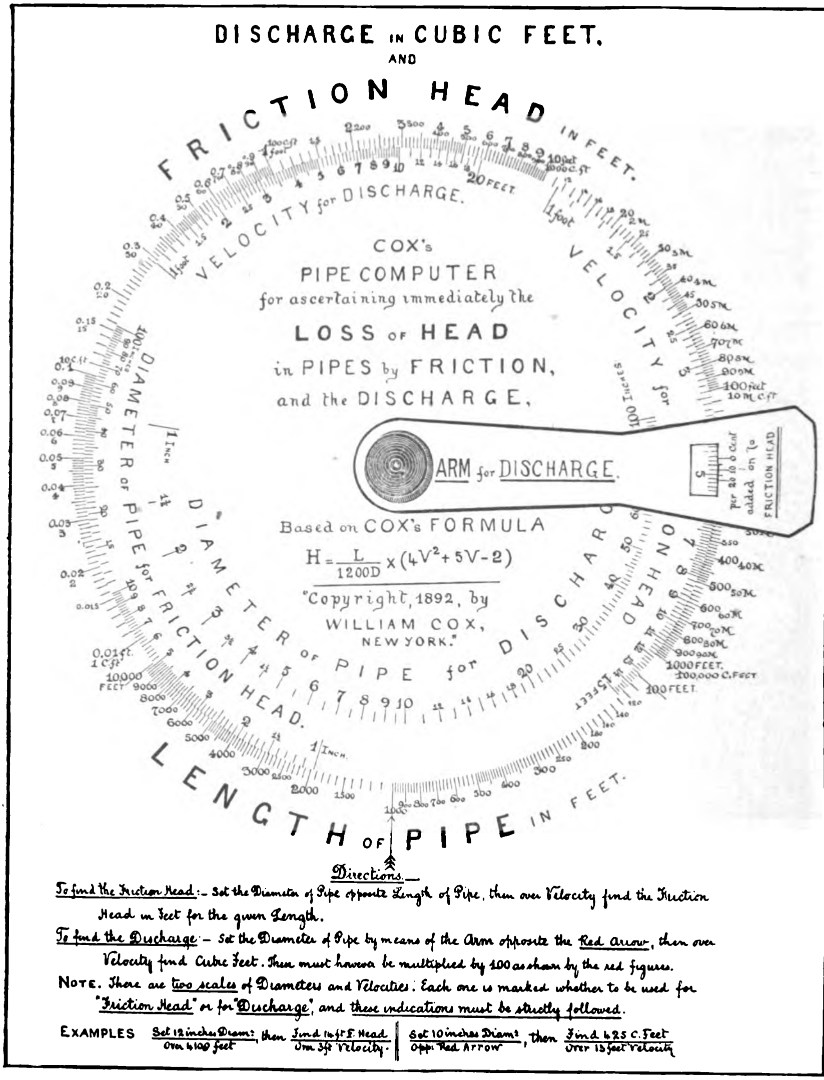
Fig. 2.

Figure 2 represents another form of this Pocket Rule which will also be found very convenient. It is made without the spring joints, but very thin and flexible, so that curves as well as the circumferences of round objects, as small as 5 inches diameter, may be measured with it. This pattern in 4 feet can also be had with metrical measures on one side and inches on the other.

The rule shown in Fig. 1 is also made without spring joints, the workmanship and the quality being in all respects the same.

Not the least recommendation of the K. & E. Pocket Folding Rules is their moderate price, and this, combined with their accuracy and convenience, has brought them into great favor.

A PIPE COMPUTER.



IN OUR NOVEMBER issue we referred to a mechanical Computer, by means of which a variety of Pipe Problems can be almost instantly solved. This instrument, which has been pronounced by high authorities to be not only simple in construction but exceedingly efficient in use, is repre-

sented in the above figure. It consists of a graduated dial with an inner revolving graduated disc, the whole mounted on a substantial board 12 inches square, with brass centre swivel and locking nut. The scales on the Computer are graphic logarithmic ones, corresponding to the different terms of the formula, and their relative positions on the dial and disc are likewise determined by their positions in the formula. The formula adopted is the following original and simple one,

$$H = \frac{L}{1200\ D}(4\ V^2 + 5\ V - 2) \quad \ldots\ldots\ldots \text{Eq. 1}$$

which gives almost the same results as those obtained by means of Weisbach's well-known formula

$$H = \left(0.0144 + \frac{0.01716}{\sqrt{V}}\right)\frac{L.\ V^2}{5.367\ D} \quad \ldots\ldots\ldots \text{Eq. 2.}$$

The formula may be further simplified and expressed as follows,

$$H = \frac{L \times V \times C}{D} \ldots\ldots\ldots \text{Eq. 3}$$

whilst by the graphic reduction of $V \times C$ into one term we have

$$H = \frac{L \times V}{D} \ldots\ldots\ldots \text{Eq. 4}$$

whence

$$\frac{H}{V} = \frac{L}{D} \quad \ldots\ldots\ldots \text{Eq. 5}$$

in which

H = Friction Head in feet,
V = Actual Velocity of the water in feet per second,
L = Length of Pipe in feet,
D = Diameter of Pipe in inches.

Equation 5 is the form adopted in this Computer, and the method of effecting a calculation is exceedingly simple, all that is required being to set the given length L on the disc opposite the given diameter D on the dial, when opposite the velocity V on the disc, is *at once* found the friction head H on the dial. It will be evident that from this very simple arrangement of the terms of the problem, we can at once find a fourth term when *any three terms* are known, so that if the head and length are given we can at once find a suitable diameter of pipe to discharge the water at a desired velocity, and then ascertain the consequent volume of discharge.

To increase the usefulness of the Pipe Computer, scales have been added by means of which the Discharge in cubic feet per minute for any given diameter of pipe and velocity of flow may be at once ascertained, these scales answering to the formula

$$\left.\begin{array}{r}\text{Discharge in } C.\\ \text{feet per Min.}\end{array}\right\} = \text{Velocity} \times D^2 \times 0.7854 \times \frac{60}{144}$$

$$= \text{Velocity} \times D^2 \times 0.32725$$

In this case the constant 0.32725 is eliminated by the position of the scales, so that three terms only remain. To bring these therefore into the same form as equation 5, we have

$$\frac{\text{Discharge}}{\text{Velocity}} = \frac{\text{Diameter}}{1}$$

The term 1 is represented by an arrow on the dial, to which the diameter is set by means of an arm having radial edges; the discharge for the given diameter is then at once found opposite any desired velocity. On this arm is also a small scale of percentages, with which 5 to 30 per cent. may be at once added on to the friction head. This scale will be found very useful when by reason of the condition of the pipes it is desired to make allowances for greater friction than would be the case for clean cast iron pipes. It will also be useful for those cases in which riveted pipes are used, where it is customary to add 20 per cent. to the friction head.

This Pipe Computer will be found particularly useful in those numerous cases in which the length of pipe and the head alone are known, and it is desired to find a suitable diameter of pipe and velocity of flow, to obtain a given horsepower by means of a turbine or water wheel.

One great merit of this Computer is that by its means comparisons of various combinations of head, diameters, etc., with their results, may be very quickly made, and the most appropriate selected, thus saving, what is in such cases, by the ordinary methods of computation, a laborious undertaking.

Examples.

1. Given:—Pipe 12 inches in diameter, 4100 feet long, and 3 feet Velocity.

   Find, Friction Head,

$$\frac{\text{Set 12 in. Diameter}}{\text{over 4100 feet}},\ \text{then}\ \frac{\text{Find 14 ft. F. Head}}{\text{over 3 feet Velocity}}$$

2. Given:—Pipe 10 inches diameter, and 13 feet Velocity.

   Find, Discharge per minute.

$$\frac{\text{Set 10 in. Diam.}}{\text{Opposite Arrow}},\ \text{then}\ \frac{\text{Find 425 cub. feet}}{\text{over 13 ft. Velocity.}}$$

3. Given:—Pipe 8 inches diameter, 900 feet long, and 30 feet head.

Find, Velocity and Discharge.

$$\frac{\text{Set 8 in. Diam.}}{\text{Over 900 feet}}, \text{ then } \frac{\text{Under 30 feet head}}{\text{Find 8.4 ft. Velocity.}}$$

$$\frac{\text{Set 8 in Diam.}}{\text{Opposite Arrow}}, \text{ then } \frac{\text{Find 175 cub. feet}}{\text{Over 8.4 ft. Velocity.}}$$

THE "LEPHAY" LUMINOUS COMPASS.

A CONSIDERABLE amount of attention has been attracted by a new form of luminous compass invented by Lieut. J. Lephay, of the French Navy. It consists essentially of an ordinary Thomson compass, and differs but little from the usual arrangement so far as its use in daylight is concerned. The card may, if desired, be illuminated at night in the usual manner, so that in the event of any failure of the Lephay apparatus the compass may be used in the ordinary manner. By using a combination of lenses and mirrors, M. Lephay throws from the binnacle lamp a vertical line of light upon the interior side of the compass box, between the card and the glass. This line, which may be produced upon any desired point of the inside of the periphery, is, for the time being, a fixed line, and bears a known relation to the line of the ship's keel. From another combination of lenses and mirrors above the centre of the card, M. Lephay throws upon the interior side of the compass box a second ray of light, which, when the apparatus has been properly adjusted, moves round as the card moves. This line, being of a different length, is easily distinguishable from the other one, and it may be temporarily set so as to bear any desired relation with any point on the card. In steering, all the helmsman has to do is so to use his wheel as to keep the two lines in one. The officer of the watch, instead of ordering a certain course to be steered, uses the ordinary illumination of the card, and by its aid heads the ship exactly to the desired point. He then, by means of buttons fitted for the purpose, moves the lines of light so that, the ship being on her course, both are in one; and having done this he shuts off the ordinary illumination and leaves the card in darkness. The steersman, from that time until the course may be altered, need only take care that he sees before him one line and not two. The officer can alter the course without again looking at the card, by turning a button to the extent desired, and the line, which is not subject to the motion of the card, appears in a new place. By means of the helm the other line is then made one with it, and the course is changed as desired.—*The Mechanical World.*

TABLE OF SLOPES, WITH THEIR EQUIVALENTS IN VARIOUS DESIGNATIONS.

Per Cent.	One in—	Degrees.	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees.	Inches per Yard.	Feet per Mile.
		° ′					° ′		
0.019	5280	0 00.65	0.007	1	1.12	89	0 38.5	0.40	59.3
0.038	2640	0 01.3	0.014	2	1.14	88	0 39.0	0.41	60.0
0.057	1760	0 01.95	0.020	3	1.15	87	0 39.5	0.41	60.7
0.076	1320	0 02.6	0.027	4	1.16	86	0 40	0.42	61.4
0.095	1056	0 03.25	0.034	5	1.18	85	0 40½	0.42	62.1
0.114	880	0 03.9	0.041	6	1.19	84	0 41	0.43	62.9
0.133	754	0 04.55	0.048	7	1.20	83	0 41½	0.43	63.6
0.151	660	0 05.2	0.055	8	1.22	82	0 42	0.44	64.4
0.170	587	0 05.85	0.061	9	1.23	81	0 42½	0.44	65.2
0.189	528	0 06.5	0.068	10	1.25	80	0 43	0.45	66.0
0.379	264	0 13	0.136	20	1.27	79	0 43½	0.46	66.8
0.568	176.	0 19.5	0.204	30	1.28	78	0 44	0.46	67.7
0.757	132	0 26	0.273	40	1.30	77	0 44½	0.47	68.6
0.947	105.6	0 32.5	0.341	50	1.32	76	0 45	0.47	69.5
1.00	100	0 34.5	0.36	52.8	1.325	75½	0 45½	0.477	70.0
1.01	99	0 34.8	0.36	53.3	1.333	75	0 46	0.48	70.4
1.02	98	0 35.1	0.37	53.9	1.35	74	0 46½	0.49	71.3
1.03	97	0 35.4	0.37	54.4	1.37	73	0 47	0.49	72.3
1.04	96	0 35.8	0.38	55.0	1.39	72	0 48	0.50	73.3
1.05	95	0 36.2	0.38	55.6	1.41	71	0 48½	0.51	74.4
1.06	94	0 36.6	0.38	56.2	1.43	70	0 49	0.51	75.4
1.07	93	0 37.0	0.39	56.8	1.45	69	0 50	0.52	76.5
1.09	92	0 37.4	0.39	57.4	1.47	68	0 50½	0.53	77.6
1.10	91	0 37.8	0.40	58.0	1.49	67	0 51½	0.54	78.8
1.11	90	0 38.2	0.40	58.7	1.52	66	0 52	0.55	80.0

Per Cent.	One in—	Degrees. ° ′	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees. ° ′	Inches per Yard.	Feet per Mile.
1.54	65	0 53	0.55	81.2	2.44	41	1 24	0.88	129
1.56	64	0 53½	0.56	82.5	2.50	40	1 26	0.90	132
1.59	63	0 54½	0.57	83.8	2.56	39	1 28	0.92	135
1.61	62	0 55½	0.58	85.1	2.63	38	1 30	0.94	139
1.64	61	0 56	0.59	86.6	2.70	37	1 33	0.97	143
1.67	60	0 57	0.60	88.0	2.78	36	1 35	1.00	147
1.69	59	0 58	0.61	89.5	2.86	35	1 38	1.03	151
1.70	58.7	0 58½	0.614	90.0	2.94	34	1 41	1.06	155
1.72	58	0 59	0.62	91.0	3.00	33.3	1 43	1.08	158
1.745	57.29	1 00	0.628	92.2	3.03	33	1 44	1.09	160
1.75	57	1 00½	0.63	92.6	3.12	32	1 47	1.12	165
1.78	56	1 01½	0.64	94.3	3.23	31	1 51	1.16	170
1.81	55	1 02½	0.66	96.0	3.33	30	1 55	1.20	176
1.85	54	1 04	0.67	97.8	3.45	29	1 58	1.24	182
1.89	53	1 05	0.68	99.6	3.49	28.64	2 00	1.26	184
1.89	52.8	1 05	0.68	100	3.57	28	2 03	1.28	189
1.92	52	1 06	0.69	101	3.70	27	2 07	1.33	195
1.96	51	1 07½	0.71	103	3.79	26.4	2 10	1.36	200
2.00	50	1 09	0.72	105.6	3.85	26	2 12	1.38	203
2.04	49	1 10	0.74	108	4.00	25	2 17	1.44	211
2.08	48	1 11½	0.75	110	4.17	24	2 23	1.50	220
2.13	47	1 13	0.77	112	4.35	23	2 29	1.57	230
2.17	46	1 15	0.78	115	4.55	22	2 36	1.64	240
2.22	45	1 16½	0.80	117	4.76	21	2 44	1.71	251
2.27	44	1 18	0.82	120	5.00	20	2 52	1.80	264
2.33	43	1 20	0.84	123	5.24	19.08	3 00	1.89	277
2.38	42	1 22	0.86	126	5.26	19.00	3 01	1.90	278

Per Cent.	One in—	Degrees.	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees.	Inches per Yard.	Feet per Mile.
		° ′					° ′		
5.56	18.00	3 11	2.00	293	13.89	7.20	7 55	5.00	733
5.68	17.60	3 15	2.05	300	14.00	7.14	7 58	5.04	739
5.88	17.00	3 22	2.12	311	14.05	7.11	8 00	5.06	742
6.00	16.66	3 26	2.16	317	14.30	7.00	8 08	5.14	754
6.25	16.00	3 35	2.25	330	15.00	6.67	8 32	5.40	792
6.67	15.00	3 49	2.40	352	15.15	6.60	8 37	5.46	800
6.99	14.30	4 00	2.52	369	15.84	6.31	9 00	5.70	836
7.00	14.29	4 00	2.52	370	16.00	6.25	9 05	5.76	845
7.14	14.00	4 05	2.57	377	16.67	6.00	9 28	6.00	880
7.57	13.20	4 20	2.73	400	17.00	5.88	9 39	6.12	898
7.69	13.00	4 24	2.77	406	17.04	5.87	9 41	6.14	900
8.00	12.50	4 35	2.88	422	17.63	5.67	10 00	6.35	931
8.33	12.00	4 46	3.00	440	18.00	5.55	10 12	6.48	950
8.75	11.43	5 00	3.15	462	18.94	5.28	10 44	6.82	1000
9.00	11.11	5 09	3.24	475	19.00	5.26	10 46	6.84	1003
9.11	11.00	5 12	3.27	480	19.44	5.14	11 00	7.00	1027
9.47	10.60	5 24	3.41	500	20.00	5.00	11 19	7.20	1056
10.00	10.00	5 43	3.60	528	21.00	4.76	11 52	7.56	1109
10.51	9.51	6 00	3.78	555	21.26	4.70	12 00	7.65	1122
11.00	9.11	6 17	3.96	581	22.00	4.55	12 24	7.92	1162
11.11	9.00	6 20	4.00	587	22.22	4.50	12 31	8.00	1173
11.36	8.80	6 29	4.09	600	23.00	4.35	12 57	8.28	1214
12.00	8.33	6 51	4.32	634	23.09	4.33	13 00	8.31	1219
12.28	8.14	7 00	4.42	648	24.00	4.17	13 30	8.64	1267
12.50	8.00	7 07	4.50	660	24.93	4.01	14 00	8.98	1316
13.00	7.69	7 24	4.68	686	25.00	4.00	14 02	9.00	1320
13.26	7.54	7 33	4.77	700	26.00	3.85	14 34	9.36	1373

(*To be continued.*)

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ADJUSTMENTS OF SURVEYING INSTRUMENTS. IV.

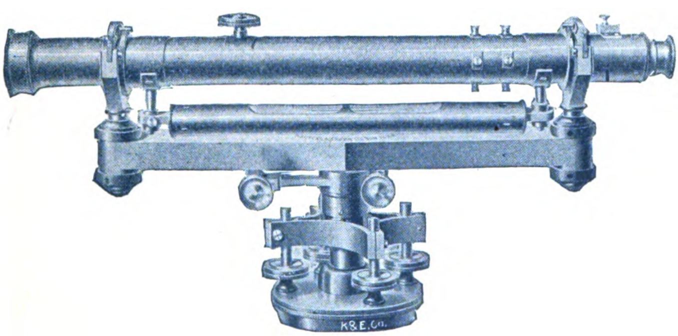


Fig. 1.

WE HAVE SHOWN that there are of necessity in the Level certain adjustments which require to be made by the engineer or surveyor himself. These are,

1st. The Line of Collimation,

2nd. The Level Bubble, and 3rd. The Wyes.

The adjustment of the *Line of Collimation* consists in making the intersection of the cross hairs coincide with the optical axis of the telescope.

The adjustment or the *Level Bubble* consists in making the bubble axis $G\ H$ parallel to the telescope axis of revolution $A\ B$, and consequently to the line of collimation, so that the bubble may correctly show when the line $A\ B$ is perfectly horizontal.

The adjustment of the *Wyes* consists in making the bubble axis, and with it the telescope axis, perpendicular to the spindle or centre $E\ F$ of the instrument.

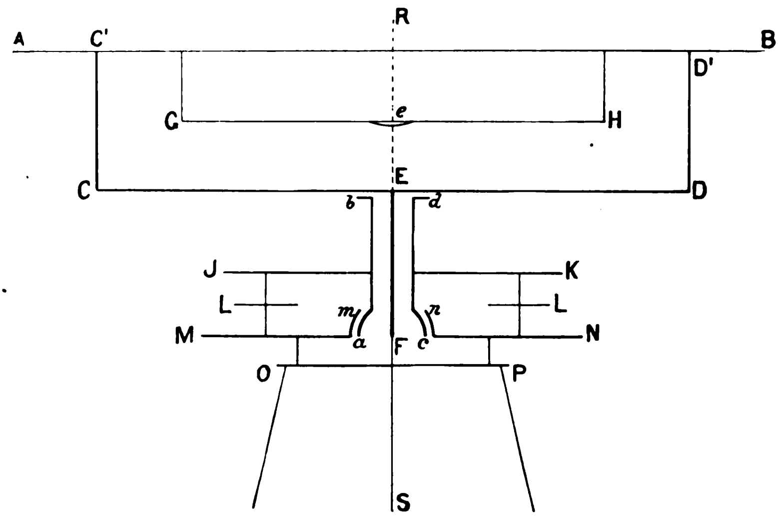


Fig. 2.

When these three adjustments are effected, then the lines $A\ B$, $C\ D$ and $G\ H$ will be parallel to one another, and also perpendicular to the line $E\ F$ as shown in Fig. 2.

To adjust the Line of Collimation, first set up the Level firmly on its tripod, then bring the cross hairs into the focus of the eye-glass by means of the milled head at the eye-piece end of the telescope, so that they may be perfectly distinct and well defined. Now unlock and open the clips of the wyes, so that the telescope can turn round freely in its bearings. Direct the telescope upon some distant object, with clearly defined vertical or horizontal straight lines, and focus the objective so that the object may be clearly seen without parallax. Note that after the eye-piece has been adjusted as above stated, it should not again be touched, the remaining work of focussing being done by the objective alone. Now clamp the

centres, and by means of the tangent screw bring one of the cross hairs to coincide exactly with the vertical or horizontal *line* selected, then turn very carefully, without in any way disturbing the instrument, the telescope half way round in its wyes, when, if the same hair again coincides exactly with the line, this hair is in adjustment, and we then proceed to try the other hair in the same manner. If this hair coincides also in both positions, then the line of collimation is in adjustment, and the intersection of the cross hairs will cover a given distant point throughout the whole revolution of the telescope in its wyes.

If, however, when the telescope is turned half way round in its bearings, the cross hair does not in its reversed position coincide exactly with the line, but lies to one side of it, then this difference must be corrected, remembering that the method of reversion, just made use of, has made the error not only apparent, but has doubled it, so that half the error only must be corrected by means of the capstan-headed screws which hold the cross hair ring, taking note to make the adjustment with the two screws which are at right angles to the cross hair, and to move the ring in the direction which would *seemingly* increase the error. Proceed now in the same manner with the second cross hair, after which verify the whole by directing the intersection of the cross hairs upon a fixed distant point. If the intersection of the hairs does not cover this point throughout a complete revolution of the telescope in the wyes, it is probable that the adjustment of the first cross hair has been disturbed by the adjustment of the second one, and it must consequently be again verified in the same manner as before. If it is however found to be correct, then the eye-piece tube is not perfectly centered, and must be brought to coincide with the line of collimation by means of the four capstan-headed screws next the eye end of the telescope.

It may not, perhaps, be out of place here to say a few words about focussing the telescope, as we have come across more than one case of persons proceeding in such a manner that they were "sure there were no cross hairs in the telescope."

The eye-piece must first be adjusted to bring its focus upon the cross hairs, the telescope being directed during the process towards the sky, or the objective being thrown entirely out of focus, so that no image may be seen other than that of the cross hairs, when the eye-piece is adjusted by moving it in or out by means of the milled-headed screw. These hairs then stand out clear and well defined against the light background. Now adjust the objective, moving it in or out, until the image of the object sighted is brought into proper focus, according to its distance from the observer. When the adjustment is correctly made, the image formed by the objective, and the eyepiece focus, will both be coincident with the plane of the cross hairs, and these will appear to be an *integral part of*

the image, both being clearly and distinctly defined, with the image intersected by the cross hairs.

If, however, the objective is not correctly adjusted, so that the image does not coincide exactly with the cross hairs, then when the eye is moved a little from side to side, it will be noticed that the cross hairs are *not* an integral part of the image, as they will be seen to cover different portions of the image in accordance with the varying position of the eye. This seeming movement of the hairs is called Parallax, and when it exists, it is impossible to fix the intersection of the cross hairs upon a definite point, so that the accurate determination of a plane or an angle is then out of the question. When, therefore, parallax exists, it must be removed by refocussing the objective, so as to bring the image exactly into the plane of the cross hairs. If then the eye-piece has also been properly focussed, parallax will not exist, but the image will appear bright and clear, intersected by the cross hairs, immovably covering the same portion of the image, whatever may be the position of the eye.

The eye-piece is adjusted to suit the operator's eye sight, and should not for some time require altering, unless the instrument is used by another person, but the objective must be focussed for every object sighted, when the distance is not the same, as its focus varies in every case with the distance of the object.

Care must be taken to correct any error of parallax before proceeding to adjust the line of collimation as described.

(*To be continued.*)

BOTH'S SECTION-LINER AND SCALE-DIVIDER.

In Volume I, page 189, we gave a full description of the above valuable instrument, and showed how it is specially adapted to section-lining and the making of scales of all kinds, with neatness, accuracy and ease. As the accuracy of the instrument in making scales is dependent upon the correct setting of the arm, a vernier is put on this when desired, by means of which readings may be made to 10 minutes, and by estimation to 5 minutes. This improvement, the extra cost of which is but small, will be appreciated by all who require an accurate and convenient Section-Liner.

THE METRIC SYSTEM.

THE FOLLOWING circular has been sent out for publication by the New Decimal Association :—

"When in the month of June, 1891, a combined deputation from the New Decimal Association and the Associated Chambers of Commerce waited upon Mr. Goschen, he, in reply to their request that a Select Committee should be appointed to inquire into the need of reform, said that he would not oppose the appointment of such a committee, but that before any decided move on the part of the Government could be made, the popular voice must be heard expressing a desire for the proposed change. Since that date the New Decimal Association has been actively engaged in distributing information on the subject and in securing extended support. The present Chancellor of the Exchequer and President of the Board of Trade have been in turn asked to hear the views of the leaders of this movement, and have promised to receive a deputation on the 25th January next.

"When it is mentioned that it is expected that the Duke of Westminster and other Peers, the Agents-General for Victoria, the Cape of Good Hope, and Queensland, several Members of Parliament, and delegates from the principal Chambers of Commerce, and from the Trade Councils of Manchester, Sheffield, Glasgow, etc., have promised to take part in the proposed demonstration, it will be recognized that there is some reasonable evidence put forward that the subject is obtaining sufficient interest to warrant the demand of the New Decimal Association for the appointment of a Select Committee to inquire into the whole question.

"This subject has lately received much attention in the United States of America and in the Colony of Victoria. On the 21st September last the Melbourne Legislative Assembly adopted a motion favoring a universal union for the introduction of the decimal system in money, weights and measures. In the same month the Trades Union Congress at Glasgow passed a resolution in favor of the adoption of the system, and directed its Parliamentary Committee to do their best to secure that result.

"When it is remembered that there are over four hundred millions of the globe's inhabitants using the metric system, it must be admitted that the New Decimal Association makes out a strong case for the need of reform in our complicated system of weights and measures, especially when it is remembered that, were England now to adopt the metric system, it is quite reasonable to believe that one universal system of weights and measures would rule throughout the entire globe. Not the least argument in favor of reform in this direction is, that by making the proposed

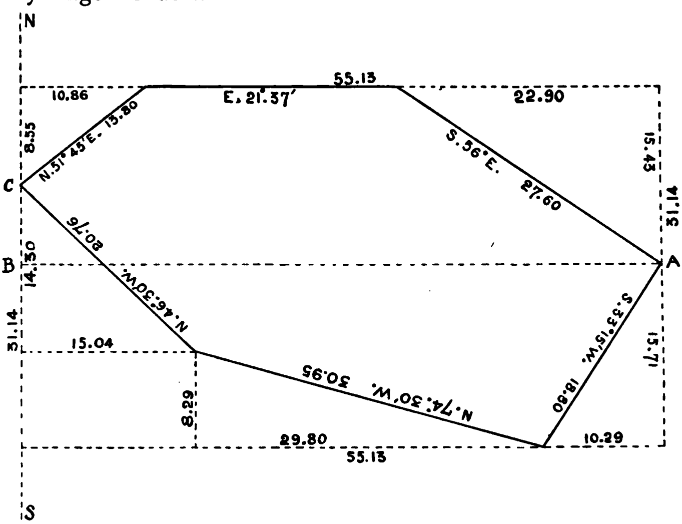
change, the time at present expended in our schools in learning the almost endless tables of weights and measures and sums of compound arithmetic would be no longer necessary, and a saving of a period of time equal to one year's training would be effected.

"It is much to be hoped that Sir William Harcourt and Mr. Mundella will give all the assistance they can in support of the object of the movement, viz., the adoption at an early date of the metric system of weights and measures in the United Kingdom."

COMPUTING AREAS.

Editor Compass :—

I send you a little modification of the usual method of computing areas from a boundary survey, which, although not new, has not, I think, been described in any of the text books, and may possibly interest some of your younger readers.



Draw a diagram of the field to be computed. Unless the boundary is very irregular, an instrumental plot is unnecessary; a diagram by eye is sufficient in most cases.

Through the most Easterly and Westerly corners of the plot, draw meridians with dotted lines. Through the most Northerly and Southerly corners draw East and West lines to meet the meridians, thus inclosing the figure in a rectangle. From every corner not touched by this rectangle draw *N* and *S* and *E* and *W* lines to intersect the lines of the rectangle; the space included between the rectangle and the figure whose

area is desired will thus be divided into right angled triangles, and occasionally a rectangle.

The bases and perpendiculars of these triangles, it will be seen, represent the Latitudes and Departures of the different sides of the figure to be computed.

These are computed in the usual way, and written upon the lines which represent them. The addition of the numbers on opposite sides of the inclosing rectangle will show the error of closure, which is corrected in the usual way. The difference between the area of the inclosing rectangle and the sum of the areas of the triangles and rectangles included will of course give the area desired.

This method thus dispenses with the use of double meridian distances; the numbers to be manipulated are mostly smaller than when those distances are employed, and the calculator sees before him continually the *effect* of every operation which he performs.

The figure accompanying this is the same that is computed by double meridian distances on page 104 of the late revision of Davies' Surveying by Prof. Van Amringe.

Suppose now that a certain area is to be parted off the South side of the figure, by an E. and W. line, and that it is probable that the division line will fall near the corner marked *A*. From *A* draw an E. and W. line to *B*. The length of this line is known, being the same as that of the inclosing rectangle. The distance of the point *B* from the corner *C* is readily found by the addition and subtraction of the Latitudes on opposite sides of the figure, and as the angle at *C* is known, the area of the small triangle cut off by *A B* can be computed. The areas of the other triangles and rectangle surrounding the South part of the figure are already on hand, having been obtained in the computation of the original figure, so that the area parted off by *A B* is found with very little labor. The excess or deficiency between this line and the line of the required area is now in the form of a trapezoid which is computed in the usual way.

If the dividing line is not to be parallel with the lines of the inclosing rectangle, the angle which it makes with them is of course known, so that the area of the triangle included between *A B* and a line starting from *A* and running in the required direction can be found, and from this new base the Trapezoid of excess or deficiency can be computed as before.

This method can hardly be recommended to the entire exclusion of the usual way, but in many cases it effects a considerable economy of labor.

When a many sided figure is to be divided into several parts, this method is very advantageous.

Very truly yours, R—— S——.

THE COMPASS.

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All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

COMPUTING THE CONTENTS OF RAILROAD AND OTHER CUTTINGS AND EMBANKMENTS.

WE HAVE RECEIVED the following communication :—

"To the Editor of THE COMPASS.

"I desire to call to your attention a method of making preliminary estimates, used by me, and so far as I know original. I find it quick and accurate; the only theory is that similar triangles vary as square of their sides. Making a table of the areas of triangles for various slopes, all having a depth of 1 foot, and multiplying each by 3.71, I obtain a table of co-efficients of quantities for 100 feet.

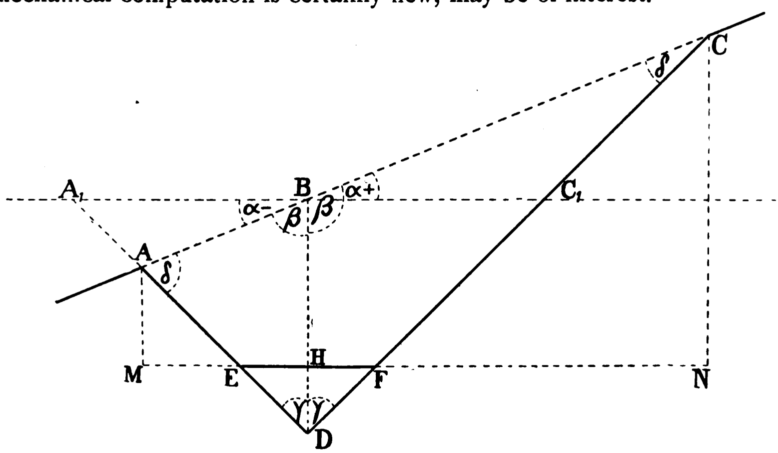
"To the given level cutting or fill I mentally add the centre height of the grade prism, say on 18 feet roadbed and $^1/_1$ slopes, 9 feet.

"If the given cut is, say 7 feet, add 9 feet; new cut 16 feet. Set 1 of *C* on 16 of *D*: read quantity on *A* above co-efficient on *B*. For each operation subtract 298.5 yards on $^1/_1$—18 feet beds.

"I can, of course modify the method to include quantities when the ground has two slopes, one on each side of centre."

Yours truly, C. S. Y.

In this connection the following method, which in its application to mechanical computation is certainly new, may be of interest.



In the above figure let

$A\ B\ C =$ the natural surface of the ground,
$B\ H =$ the centre height of cutting or embankment,
$E\ F =$ the width of roadbed,
$\alpha =$ the angle of the surface slope with the horizon, $= A\ B\ A_1$,
$\beta =$ the angle of the surface slope with the centre height, $= A\ B\ H$,
$\delta =$ the angle of the surface slope with the side slope, $= B\ A\ D$,
$\gamma =$ the half apex angle $= A\ D\ B$.

It is evident from the figure,

1st, — *in the case of a cutting*,

When the surface $B\ A$ slopes down from the centre height, $\beta = 90^\circ - \alpha$, and when the surface $B\ C$ slopes up from the centre height, $\beta = 90^\circ + \alpha$.

2nd, — *in the case of an embankment*,

When the surface slopes down from the centre height, $\beta = 90^\circ + \alpha$, and when the surface slopes up from the centre height, $\beta = 90^\circ - \alpha$; whence the angle α is either *plus* or *minus*, and when the ground surface is level, then $\alpha = 0^\circ$ and $\beta = 90^\circ$.

The apex angle 2γ is easily ascertained for side slopes of 1 to 1, $1\frac{1}{4}$ to 1, $1\frac{1}{2}$ to 1, etc., being for 1 to 1 = 90°, whence $\gamma = 45^\circ$

$1\frac{1}{4}$ to 1 = $102^\circ\ 42'$ " $\gamma = 51^\circ\ 21'$

$1\frac{1}{2}$ to 1 = $112^\circ\ 38'$ " $\gamma = 56^\circ\ 19'$

The angle δ is therefore $= 180° - (\beta + \gamma)$.

By the method which we propose for computing contents, the only data required to be ascertained on the ground are,

$B\,H$, the centre height, and

α, the angle of the surface slope with the horizon,

the other angles being determined as shown from the side slopes.

Now the area of the triangle

$$A\,B\,D = \frac{B\,D \times A\,D \sin \gamma}{2} \text{..........Eq. 1.}$$

but
$$A\,D = \frac{B\,D \times \sin \beta}{\sin \delta}$$

therefore area of

$$A\,B\,D = \frac{B\,D^2 \times \sin \beta \times \sin \gamma}{2 \sin \delta} \text{.......Eq. 2.}$$

and the cubic contents for any length L feet in cubic yards.

$$= \frac{B\,D^2 \times \sin \beta \times \sin \gamma \times L}{2 \sin \delta \times 27} \text{..........Eq. 3.}$$

If we now take $\frac{\sin \beta \times \sin \gamma}{54 \sin \delta}$ to be equal to K, then the contents of the Triangular Prism

$$A\,B\,D = B\,D^2 \times L \times K \text{.............Eq. 4.}$$

We have worked out from the above formula a table of values of K for different surface slopes, with β varying from 90° to 45° and from 90° to 135°, and for side slopes of 1, $1\frac{1}{4}$ and $1\frac{1}{2}$ to 1, but to make these tables more easily applicable, the corresponding α angles are designated instead of β, being therefore from 0° to 45° *minus*, and from 0° to 45° plus, whence as stated, it is but required to know the centre height $B\,D$ and the surface angle α, in order to obtain the contents of the Triangular Prism. We also obtain from another table the centre height $H\,D$ of the grade prism $E\,F\,D$ for different side slopes and widths of roadbed, by means of which and equation 4, the contents of the grade prism may be in like manner obtained, this amount being then deducted from the contents of the triangular prism $A\,B\,D$.

*Example.** Let centre height $B\,H = 24.4$ feet, Roadbed 12 feet, Side Slopes $1\frac{1}{2}$ to 1, Length of Section 100 feet, $\alpha - = -12°$, $\alpha + = +15°$, $H\,D = 4$ feet, then we have

* Taken from *Computation from Diagram of Railway Earthwork* by A. M. Wellington, C. E.

$K = 0.0465$ for $+ 15°$ and

$K = 0.02107$ " $- 12°$

whence cubic contents of Prism $B\ C\ D$

$= 28.4 \times 28.4 \times 0.0465 \quad \times 100 = 3750$

and of Prism $A\ B\ D$

$= 28.4 \times 28.4 \times 0.02107 \times 100 = 1700$

total contents 5450

less contents of grade prism 89

leaves 5361 cubic yards as the contents of the section $A\ C\ F\ E\ A$.

To further simplify the labor, the writer has designed and copyrighted a "Prism Contents Computer," consisting of a graduated dial with an inner revolving graduated disc, the scales of which correspond to the four factors of equation 4. The method of procedure is thus exceedingly simple, being as follows:—Set the centre height $B\ D$ on the disc to coincide with the surface slope angle α on the dial, then will be at once found the contents in cubic yards on the dial, coinciding with the length of the prism on the disc.

If the centre height and the angle α are different at each end of the prism, take half the sum of each, and proceed as shown.

This method of computation may also be employed when the field notes are kept in the usual way, giving centre height, distance out from the centre to each slope-stake, and height of the slope-stakes above or below grade; thus, the difference between the centre height and the height of slope stake above or below grade, divided by the distance of the slope-stake from the centre, gives the tangent of the angle of the surface slope $= \alpha -$ or $\alpha +$.

Example. Let in the figure

$$\begin{array}{lll} M\,H = 18 \text{ ft.} & & N\,H = 36 \text{ ft.} \\ & B\,H = 15 \text{ ft.} & \\ A\,M = 9 \text{ ft.} & & C\,N = 27 \text{ ft.} \end{array}$$

then

$$\frac{B\,H - A\,M}{M\,H} = \frac{15 - 9}{18} = 0.333 = \tan 18° \, 25'$$

and

$$\frac{C\,N - B\,H}{N\,H} = \frac{27 - 15}{36} = 0.333 = \tan 18° \, 25'$$

The cubic contents may now be computed as described, either by equation 4 or by the "Prism Contents Computer," or if preferred, the contents may be obtained direct from the field notes with the Computer by means of special scales provided to solve the equation commonly employed, namely

$$\text{Contents} = \frac{B\,D \times M\,H \times L}{54}$$

As already stated, however, this method involves more labor in the field, and in its results is not more accurate than the other; the only advantage is perhaps, that when the ground slope is uniform from A to C, the contents of the triangle $A\ C\ D$ may be obtained by one operation, instead of two, as is necessary when the contents are obtained by means of the surface angle α.

To render the table of values of K more complete, the tangent of the different surface slope angles is given in a separate column, so that recourse need not be had to any other tables.

It is not, of course, intended that this device should supersede the more accurate mode of computation by means of the prismoidal formula; it will, however, especially if the Computer be used, be found a very great saver of labor when making preliminary estimates, while the results are accurate enough for such purpose.

ENGINEERING AND SURVEYING INSTRUMENTS. VI.

Clinometers.

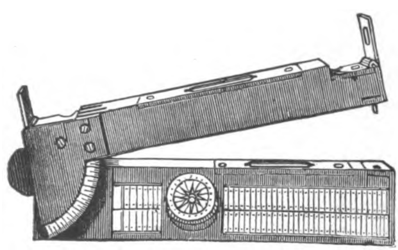


Fig. 1.

The Clinometer shown in Fig. 1, which we have already described in these columns, may also be used for obtaining the vertical height of an object when its distance is known, or the distance when the vertical height is known. The method of procedure is as follows:—

Place the instrument on some surface which is ascertained by means of the lower bubble to be level, then raise the upper leg until the object, whose distance or height is sought, is intersected by the cross hairs of one of the sights, the object being viewed through the pinhole of the other sight, then read off on the quadrant the angle subtended by the object.

When the object is above the level of the eye, the pinhole sight next to the joint must be used, thus giving an angle of elevation, but when the object is below the level of the eye, the other pinhole sight must be used, the reading being then an angle of depression.

Thus, if the angle read off on the quadrant be 11°, and the distance of the object be known to be 2500 feet, the height, as obtained from the *Table of Slopes* given in the last number of THE COMPASS would be

$$\frac{19.44 \times 2500}{100} = 486 \text{ feet}$$

above the level of the eye.

Again, if the object be known to be 3800 feet high, the distance would be

$$\frac{3800}{1027} = 3.7 \text{ miles.}$$

For an object partly above and partly below the level of the eye, two observations must be made, when the sum of the two perpendiculars will be the vertical height. To ascertain, however, the distance in such a case, we must proceed otherwise. Thus, let the angle of elevation be 40°, the angle of depression 20°, and the vertical height 1000 feet, required the distance. From the Table of Slopes,

for 20° — vertical height = 36.39 for distance 100,
" 40° — " " = 83.90 " " 100;

we have, therefore, by addition 120.29 feet vertical height for a distance of 100 feet. Now by simple proportion $\frac{100 \times 1000}{120.29} = 831.3$ feet = the distance for a vertical height of 1000 feet.

The small dimensions of this instrument preclude its use in cases where a considerable degree of accuracy is required. When such is a *sine qua non*, some other should be employed, either of the following ones being suitable and reliable, the choice being guided by individual preferences or by the nature of the work in hand.

Figure 2 consists of a square brass frame with 4 inch sides, to one corner of which is pivoted an arm, having a fine bubble attached to it. The other end of the arm is provided with a vernier reading into a quadrant divided to half-degrees, the vernier enabling angles of 3 minutes to be noted. The bubble is adjustable on the arm, while a set screw on the under edge of the arm allows of the vernier being at once set to zero of the quadrant. The instrument being square, the horizontality or verticality of any object may be ascertained. The light weight of this Clinometer, combined with its substantial construction, is an advantage which will be at once recognized.

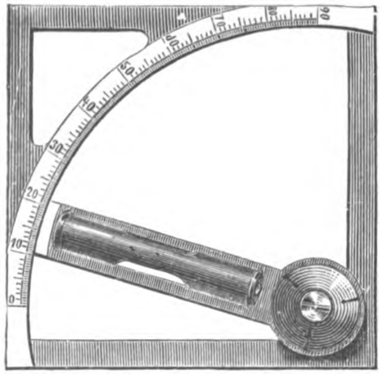


Fig. 2.

Figure 3 resembles the above in many respects, the chief difference being that it consists of a solid triangular plate with ledges attached to the two sides forming the right angle, thus giving it a broader surface to rest upon or against the object whose inclination is sought. The arc is also divided to half-degrees from zero to 50°, reading by means of the vernier on the end of the arm to 3 minutes. The vernier can be clamped in any desired position by means of the milled-headed screw on the under side of the plate, by which the bubble is moved to correspond to the slope angle. The bubble tube is also graduated, so that very slight differences of elevation or depression may be noted. The two bearing sides are each 4½ inches long.

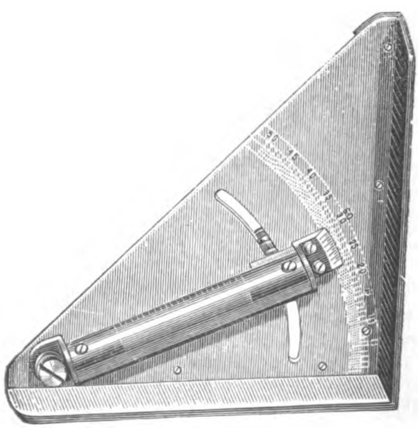
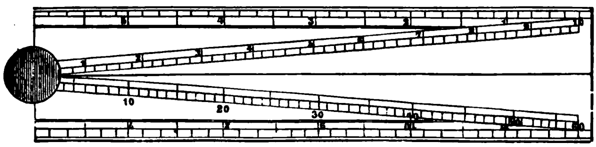


Fig. 3.

The instruments shown in Figs. 2 and 3 are designed to serve as Clinometers only. There are, however, a number of combination instru-

ments which can also be used for ascertaining slope angles, such as Compasses, Prismatic Compasses, Alt-Azimuths, etc., but by reason of their dimensions and special forms of construction, they are not as reliable or as closely divided as the Clinometers shown above. These models will be described hereafter.

THE SECTOR. I.



Before proceeding to describe the Sector it will not be inappropriate to say a few words about its inventor.

Edmund Gunter, whose name is so well known to the Surveyor, was born in Hertfordshire in 1581 of Welsh parents. His early education was acquired at the ancient Westminster school, as a Queen's foundation scholar, from which he was elected to an exhibition at Oxford, where he went in 1599 as a student of Christ Church. He graduated in due course bachelor and master of arts, then took holy orders and began to preach in 1614, and at the close of 1615 took the degree of bachelor of divinity. In his youth he had shown a great taste for mathematics, and at this time he allowed his early inclinations, which he had continued to foster, to influence his future course of life. He was appointed in 1619 to be Professor of Astronomy in Gresham College, which post he held to his death, which occurred December 10, 1626.

To Gunter's genius are due many inventions which have had an important influence upon the progress of mathematical science, amongst them being the well known Gunter's Chain, consisting of 100 links, the chief merit of which lies in the fact that 10 square chains make an acre; Gunter's Scale, which was the first attempt to make use of graphic logarithmic and other scales for the purpose of computation, and which was the origin of the now well known Slide Rule; the Sector, invented about the year 1606, which is a combination of nearly every scale required for geometrical and trigonometrical computations. It is generally believed that Gunter was also the discoverer of the variations of the declination of the magnetic needle. He it also was who introduced the terms cosine, cotangent, etc., to designate the sine, the tangent, etc., of the complement of an angle.

The Sector represented above, by means of which a great number of problems in arithmetic, geometry, trigonometry and navigation may be solved, consists generally of a folding boxwood or ivory foot rule, both sides of which are covered with various scales or lines, some being parallel with the edges of the rule, while the others radiate from the centre of the joint.

The *parallel* scales are *single lines*, that is, a line or scale on one leg is complete by itself, while the *Sectoral* or *radiating* scales are *double lines*, being in pairs, one line being on one leg and a similarly graduated line on the other leg, the two being used together for the purposes of computation.

The following are the different scales usually found on the Sector :

SECTORAL LINES, (RADIAL.)

On one side,

1. Lines of lines, (equal parts) marked .... *L.*
2. Lines of natural chords, " .... *C.*
3. Lines of natural secants, " .... *S.*
4. Lines of Polygons, " .. .. Pol.

On the other side.

5. Lines of natural sines, marked............ *S.*
6. Lines of natural tangents, 0° to 45° " .... *T.*
7. Lines " " " 45° to 75° " .... *T.*

PARALLEL LINES. (SINGLE SCALES.)

On one side.

8. Scale of 12 inches, subdivided to tenths of an inch.
9. Scale of 1 foot, divided in $10 \times 10 = 100$ equal parts, called the decimal scale, on the outer edges of the rule.

On the other side.

10. Line of logarithmic numbers, marked .... *N.*
11. Line of logarithmic sines, " .... *S.*
12. Line of logarithmic tangents, " .... *T.*

The principles of the Sector depend upon the proposition which we have already had occasion to state, namely,

When two sides of a triangle are proportional to the two sides of another triangle, each to each, and their included angles are equal, then the third side of the one bears the same proportion to the third side of the other.

To fully understand, however, the application of this principle, it is necessary that we first examine the different scales or lines which are found upon the Sector, and ascertain how they are set out.

(*To be continued.*)

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

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ADJUSTMENTS OF SURVEYING INSTRUMENTS. V.

THE NEXT ADJUSTMENT to be taken in hand is that of the Level Bubble, by which the telescope axis *A B*, and consequently the line of collimation, are made parallel to the level tube axis *G H*. To effect this, set up the instrument as before, bring the telescope over either pair of opposite leveling screws, clamp it and focus it upon some object at an average distance, say 250 to 300 feet, so that the racking out of the object glass may tend to distribute the weight more equally on each side of the centre. After unlocking and opening the clips of the wyes, bring the bubble into the centre of its run (or zero) by means of the two leveling screws under the level bar, then very carefully take the telescope out of the wyes, reverse it end for end and replace it in the wyes, then note if the bubble returns to its former position of zero. If it does not it shows that the level tube and the telescope axes are not parallel to each other. Half of the deviation shown by the bubble must be corrected by means of the leveling screws under the level bar, and the other half by means of the two clamping nuts at the eye-piece end of the level tube, by which its *vertical* position under the telescope is adjusted, as seen in Fig. 1. To

do this, the upper nut should be loosened first, and then the lower one raised or lowered according as the direction of the movement of the bubble from zero may indicate to be necessary, then secure the level tube by following up the top nut. In this connection it may be well to remark that as the bubble invariably runs to the higher level, when it moves towards the eye-piece end of the telescope, the bottom adjusting nut should be lowered, and vice versa. Having made the correction, reverse the telescope again to see if the bubble remains stationary.

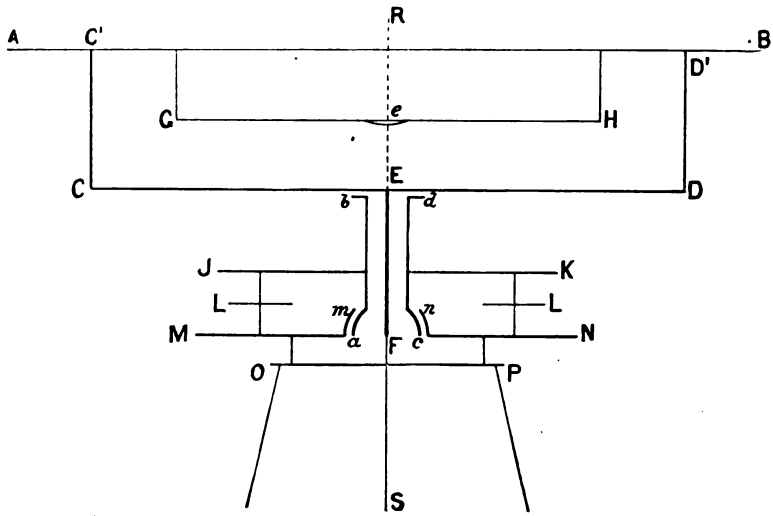

Fig. 1.

This adjustment of the level tube is called the *horizontal* adjustment, but another one, called the *lateral* adjustment also requires examining. It may happen that the telescope and level tube axes are not in the same vertical plane, or are not in parallel vertical planes, one end of the tube being laterally out of adjustment. To test this, turn the telescope gently in the wyes, so as to bring the level tube outwards to one side or the other of the level bar; if the bubble remains stationary, then this adjustment is in order. If the bubble should move toward one end of the tube, then this deviation must be corrected by means of the two side screws at the objective end of the level tube by which its *horizontal* position under the telescope is adjusted. When this is done, in order to make assurance doubly sure, examine again the horizontal adjustment of the level tube, as explained in the first paragraph.

We now proceed to the adjustment of the wyes, to ascertain if the level tube axis and the line of collimation are perpendicular to the centre

or vertical axis of revolution of the instrument, that is $A B$ and $G H$ are parallel to $C D$ and perpendicular to $R F$, so that when the telescope is leveled and turned round on its axis, the bubble will maintain a perfectly stationary position.

As in the last adjustment, bring the level bar over either pair of opposite leveling screws, and having locked the telescope in the wyes, proceed to bring the bubble to the centre of its run by means of the two leveling screws under the level bar. Now turn the telescope carefully halfway round on its axis, so that the level bar may be again over the same pair of leveling screws, but in a reversed position, and note if the bubble maintains exactly its central position. If it does, the level bar and the telescope axis are parallel, and perpendicular to the axis of revolution of the instrument. If, however, the bubble should run to one end of the tube, half the deviation must be corrected by means of the two leveling screws under the level bar and half by means of the two nuts by which the wyes are secured to the level bar, as shown in Fig. 3. When this is accomplished, place the telescope over the other pair of leveling screws and proceed as just described, afterwards repeating the operation over the first pair of screws.

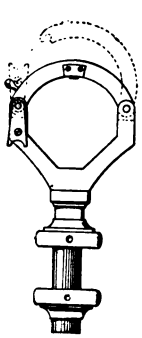

Fig. 2.

When all these adjustments have been carefully and accurately made, the engineer or surveyor may be assured that if he has a well made and reliable Level, its centre or axis of revolution is vertical, and the line of sight is horizontal, however much the telescope may be revolved in azimuth.

*PRECISION OF MEASUREMENTS.**

An experimental result whose reliability is unknown is nearly worthless. The grade of accuracy of a measurement must be adapted to the purpose for which the result is desired. The necessary accuracy must be secured with the least possible expenditure of labor.

These statements apply no less to the roughest than to the most elaborate work which the engineer is called upon to perform; they are no more true of refined scientific research than of every-day engineering and industrial practice. . . .

The thoughtful student recognizes early in his experimental work the importance of certain questions which never leave the mind of the ex-

* Extracts from *Discussion of the Precision of Measurements,* by Silas W. Holman S. B., Associate Professor of Physics, Massachusetts Institute of Technology.

perienced observer, namely— What accuracy is desired in the result? What accuracy is therefore necessary in each of the various component measurements from which the result is calculated? How reliable is the final result when obtained? The more complicated and indirect the measurement, the more difficult it becomes to answer these queries by mere inspection, and hence the greater the necessity for some systematic and rational procedure for reaching the answer . . .

All quantitative work of course involves measurements. These may be separated into two classes, viz., direct and indirect. DIRECT MEASUREMENTS are those made by methods and instruments whose indications give directly the quantity sought; e. g. measurements of distance by a scale, of weights (or masses) by an equal-arm balance, etc....

INDIRECT MEASUREMENTS are those in which the quantity measured is not given directly by observation or readings taken, but must be calculated from them. Thus in an indirect measurement the quantity sought is a function of one or more quantities which are directly measured and which may be called the component quantities....

All processes of measurement are, of course, fallible. None can give absolute accuracy, that is, none can be wholly free from error. The questions with which we have to deal then are only such as relate to the amount or character of the errors occurring, and to their *sufficient* elimination for the purpose in hand.

Inspection of the methods, instruments, and results of any direct measurements will show that the method has some discoverable sources of error, that the instruments likewise contain certain inherent sources of error, and finally that however carefully the effects of the discoverable sources are removed, some undiscovered or uncorrected sources still remain, since successive equally careful repetitions of the same measurements yield numerical results which are more or less discordant in the last one or two places of significant figures.

The existence of this discordance just referred to proves that the errors from the various sources are not constant, at least that some of them are not,—a fact which we know to be true for some of the discoverable sources. And the general rule for the variation doubtless is that under given conditions the error from any given source has a certain average magnitude about which it varies more or less, being sometimes greater, sometimes smaller than that amount. It is therefore reasonable, and will be found convenient, to regard the error from any source as made up of two portions, a constant part, viz., its average value, and a variable part. Of course either of these may be wanting in any given instance....

Take as an illustration so simple a measurement as that of the distance between two points by means of a steel tape.

There are easily discoverable such sources of error as these:

(1) Error in numbering of tape;
(2) Irregular spacing of divisions;
(3) Incorrect unit, i. e. foot not standard length;
(4) Bends in tape;
(5) Sag of tape;
(6) Stretch of tape;
(7) Error of setting zero of tape at starting point;
(8) Error of estimation of fraction of division at finishing point;
(9) Temperature not that for which the tape was graduated.

Besides these sources there are doubtless many others of greater or lesser effect, some of which might possibly be discovered by further study, but many of which are at present obscure.

Successive measurements of the same distance, especially if this be long and if the fraction of an inch to which readings are taken be small, will show discordances of greater or lesser magnitude.

Errors 5, 6, 7, 8, 9 would *vary* in amount from time to time and between different readings, and would, therefore, have variable parts. Each would tend to make the single results sometimes larger, at other times smaller, and by irregular amounts. Thus in the average result of a series of observations the variable parts of the error from any single source would in part annul itself. Also in any single observation the sum of the negative variable parts of the errors from all sources would offset in part the sum of the positive variable parts more or less completely, but seldom wholly.

The errors 1, 2, 3 and 4 would be *constant* for any given distance; also, 5 and 6 will clearly be liable to have some constant portion, as also would 9 under some circumstances. These together will make up the constant error. Some will be of one sign, some of the other, so that they will in part neutralize, but cannot be expected to wholly do so. The separate constant portions are the same in all single observations. Hence the constant error will be the same in each single reading and in the mean result....

It is of the utmost importance that we should be able to form some *estimate* of the accuracy or of the error of the result, whether that result be a single observation, a mean of a series by one method, or the mean of results by a large number of methods, and that this estimate should be expressed numerically, so far as possible. How such an estimate is arrived at, will be here indicated, and just what the measure is will be more explicitly stated in a later paragraph.

A UNIVERSAL SCALE.

We have received from Mr. J. Ernest G. Yalden a Universal Scale, which he says was the outcome of a search for a simple universal scale for the construction of verniers.

It is based on the sector principle, but instead of one sector it has thirty, placed side by side, so that any number of divisions of any length, above $\frac{1}{80}$ of an inch, up to thirty may be laid down directly on a slip of paper, without moving the slip.

The scale consists of a triangle printed on a card, having a base of 6 inches and an altitude of 6 inches. The base is divided into 30 equal parts, these parts being connected with the apex of the triangle by radial lines. A series of lines parallel to the base are drawn through the triangle, to enable one to hold parallel to the base, the paper on which the divisions are to be taken.

Some of these parallel lines are marked at their extremities 5, 6, 8, etc., these being lines of scales on which there are 5, 6, 8, etc., parts to the inch respectively, but any other such line of arbitrary parts to the inch may be found and ruled on the card.

The method of applying this scale to the dividing of a line of unknown length into any number of equal parts, is as follows:

Mark on the edge of a strip of paper the length of the line as taken from the drawing. Let us suppose it is to be divided into 12 parts. Fit it between the 0 and 12 radial lines on the scale by sliding it up and down till it fits, keeping the edge of the paper parallel to the base of the triangle. Mark the twelve parts, and then apply this to the drawing, using it as a scale.

This, the designer of the scale maintains, is far more accurate than the usual method of drawing parallels from points on a line drawn through one end of the given line; it also takes far less time and does not deface the drawing. The draughtsman can construct in like manner a scale to fit any case, and which may be used in the same manner as an ordinary scale.

The German Round Writing is the quickest ornamental writing, and is worth the trouble of learning.

The cheapest and best drawing pins are those with the point stamped out of a metal disc.

Even if liquid Indian ink be not always used, it should be available in every drawing office.

In selecting drawing instruments, only the best should be chosen. (From "Hints to Young Draughtsmen" in *The Mechanical World.*)

NEW BOOKS.

Discussion of the Precision of Measurements, with Examples taken mainly from Physics and Electrical Engineering. By Silas W. Holman, S.B., Associate Professor of Physics, Massachusetts Institute of Technology. John Wiley & Sons, New York, 1892. 8vo. cloth, 176 pages. Price $2.00.

The author in his preface says that the material presented in this volume is the outcome of several years' teaching of the subject, and that in a less complete form it was prepared for lecture notes, but that in this revised form he conceived that it might be of sufficient interest and value to merit publication.

The study of this work, if even the opportunity for applying directly the methods of investigation set forth should not present itself, cannot fail to be productive of valuable and beneficial results. We refer our reader to the extracts from the work which we give on another page, for further insight into the author's method of treating his subject.

We stated in a former number of The Compass that Keuffel & Esser Co, its publishers, had laid the foundation stones of a large and commodious building to replace the one in which they for so many years carried on their business. This step became necessary by reason of the increasing necessities of their growing business, and also that they might be in a position to maintain their reputation as the best equipped and promptest house in the trade. Possession of the new building, erected on the site occupied by their old one, was taken on the 22d February, and the labor of having everything taut and snug will soon be over.

The show rooms are spacious and well lighted, and permit of their large and carefully assorted supply of Drawing and Engineering Instruments and Materials being quickly and thorougly inspected, thus saving the purchaser's valuable time. They are also, by reason of the better accommodation, able to hold a larger stock than formerly, and are consequently in a position to continue to meet at once the increasing demands made upon it.

Several other improvements for exhibiting and handling goods have been adopted, which they will at all times be pleased to show to their friends and clients.

The Editor of The Compass will also be glad to receive in his new quarters any of our numerous subscribers who may chance to be in this city, and can make it convenient to give him a passing call.

THE COMPASS.

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CORRESPONDENCE should be addressed to the Editor of THE COMPASS, 127 Fulton Street, New York City.

All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

THE SECTOR. II.

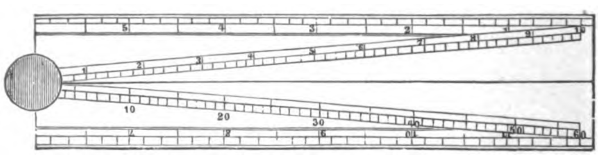

Fig. 1.

THE TRIGONOMETRICAL scales found on the Sector are, as stated in our last, the scales of Sines, Tangents, Secants and Chords. The method of constructing them will be readily understood from the diagram, Fig. 2.

1. Let $A\ C$ be the radius of any circle, and with C as centre and radius $A\ C$, describe the quadrant arc $A\ D\ B$, the angle at C being consequently a right angle. Divide the arc $A\ D\ B$ into 9 equal parts, each part being then subdivided into tenths (these as well as other subdivisions are omitted in the diagram on account of the limited space). The arc $A\ D\ B$ represents a scale of 90 *degrees*.

2. Join $A\ B$ and with centre A describe a series of short arcs between the chord $A\ B$ and the arc $A\ D\ B$, thus transferring to $A\ B$ the chords of 10°, 20°, 30°, etc. These divisions on $A\ B$ will now represent a scale of *chords* to radius $A\ C =$ chord of 60°.

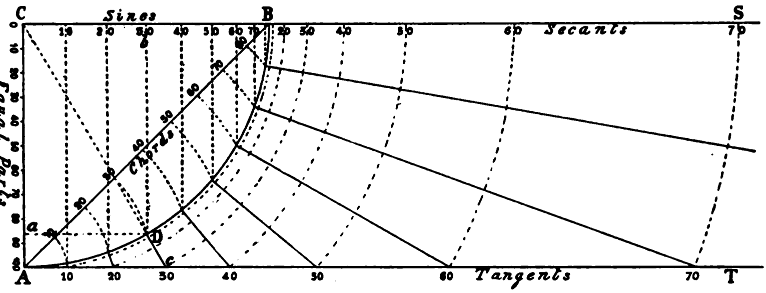

Fig. 2.

3. From the different divisions of the arc $A\ D\ B$ draw perpendicular lines to $C\ B$, and number the points of intersection from 0° at C to 90° at B, when we have a scale of *sines* to radius $A\ C$.

4. Prolong the line $C\ B$ indefinitely to S, and draw the line $A\ T$ parallel to $C\ S$. From C as centre draw radial lines through the several divisions of the arc $A\ D\ B$ until they meet the line $A\ T$, and number the points of intersection from 0° at A to 70° near T (the limits of our diagram not allowing of their being carried further); we then have on $A\ T$ a scale of *tangents*, also to radius $A\ C$.

5. With centre C describe a series of short arcs between $A\ T$ and $B\ S$, commencing with the division 10° on $A\ T$, and proceeding to 70°. The points of intersection of these arcs with $B\ S$ should be numbered from 0° at B to 70° near S, when we have a scale of *secants* to radius $A\ C$.

6. To complete the scales, divide the radius $A\ C$ into 10 equal parts, each one of these being then further subdivided into 10 other *equal parts*, making 100 in all.

Such are the various trigonometrical scales found on the Sector. A glance at the diagram will make them clear. In the triangle $C\ a\ D$, let $C\ D =$ radius $=$ 100 by the scale of Equal Parts $C\ A$, and the angle $D\ C\ a = 30°$; then $D\ a = C\ b =$ sine 30°. Now take a pair of Compasses and with one leg on centre C, take in $C\ b$, then with the same centre, transfer this distance to the scale of Equal Parts, when the other leg will fall upon the division answering to 50, which is the Sine of 30° to radius 100. The Cosine of 30° to the same radius is $D\ b = C\ a =$ 86.6, while the Tangent is $A\ c$, and the Secant $C\ c$, the lengths of which may also be taken off the scale of Equal Parts.

These scales, as shown in the diagram, may be applied to several uses, but as on the Sector they are all double ones, their usefulness is considerably increased, the measurements not being confined to the fixed scale of equal parts.

The solution of the various computations to which the Sector is applicable, is effected by means of a pair of ordinary dividers, although the most suitable for the purpose are those known as Hairspring Dividers, as the points may be set to take in a given measurement with greater ease and precision.

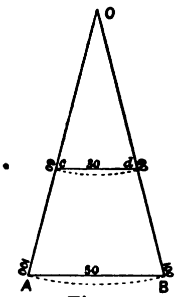

Fig. 3.

Fig. 3 will make the principles of the use of the Sector clear. We will suppose that O is the centre of the joint, and that $O\ A$ and $O\ B$ are the sectoral lines of lines, divided into 100 equal parts. We will also suppose that the legs of the instrument have been opened out until the distance from A to B is equal to 50 parts of the line of lines. Now from the properties of similar triangles

$$O\,A : A\,B :: O\,c : c\,d.$$

Let d be at the 60th division of the line of lines, then we have

$$100 : 50 :: 60 : 30 = c\,d$$

also

$$50 : 100 :: 30 : 60 = O\,d$$

In the above figure, the distances or measurements $O\ d$ and $O\ B$ are called *lateral* (or side) distances, while the distances $A\ B$ and $c\ d$ are called *transverse* (or cross) distances. Measurements are taken in the former case from the centre of the joint, and in the case of transverse distances from that line of the scales which is nearest to the inner edge of each leg, as this is in the case of every scale, the *radial* line proceeding from the centre of the instrument.

We will now give a few examples of the methods of using the Sector.

1. *To find the fourth term of a proportional*, as $8 : 14 :: 36 : x$.

With the dividers take in 8 parts on one of the lateral scales, or lines of lines; then set one of the points of the dividers upon 14 of the same lateral scale, and open out the two legs of the Sector until the other point of the dividers reaches to 14 of the other lateral scale. Now open the dividers to take in 36 parts from one of the lateral scales, and make this a transverse distance from one lateral scale to the other, when the points of the dividers will be found to reach from 63 of one scale of lines to 63 of the other scale of lines; this is therefore the fourth term sought.

If the first term of the proportion is greater than the second, it will be better to make the first term a *lateral distance*, that is to measure it from the centre upon one of the lateral scales, and make the second or

lesser term a *transverse distance*, that is, measure it across from one lateral scale to the other. The third term will also be a lateral distance, while the fourth term will be a transverse distance.

2. *To divide a given straight line into a number of equal parts, as 7.*

Take between the points of the dividers the length of the given line, and open out the Sector legs until this distance becomes a transverse distance from 70 to 70. The transverse distances 10 to 10, 20 to 20, etc., from one lateral scale to the other, will then be the divisions required.

LIGHT: ITS REFLECTION AND REFRACTION. VI.

THE BOX SEXTANT.

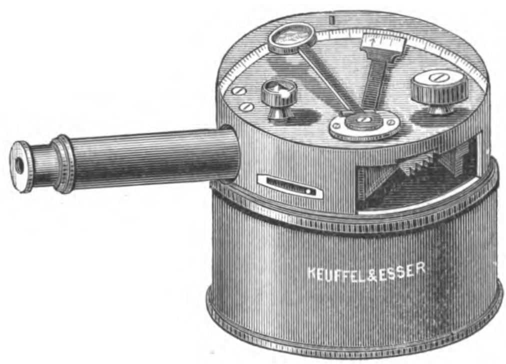

Fig. 1.

WE HAVE ALREADY explained in detail the principles upon which are based the construction and use of the Sextant. We proceed, therefore, at once to describe the Pocket or Box Sextant, an instrument which the Engineer and Surveyor will find of great use, and which would become more popular if it were more widely known.

The Box Sextant, shown open and ready for use in Fig. 1, consists of a metal cylindrical box, which, when closed, is but 3 inches diameter and 1½ inches deep. When the instrument is being used, the cap or cover is screwed to the under side, as shown, thus serving as a handle, no other support or stand being required. The telescope is inserted through the side of the box, and screwed into the inner framework, but when not required is placed in a special compartment provided for the purpose in the leather case in which the instrument is packed when not in use.

The figure, as stated, shows the Box Sextant ready for use, the chief parts being

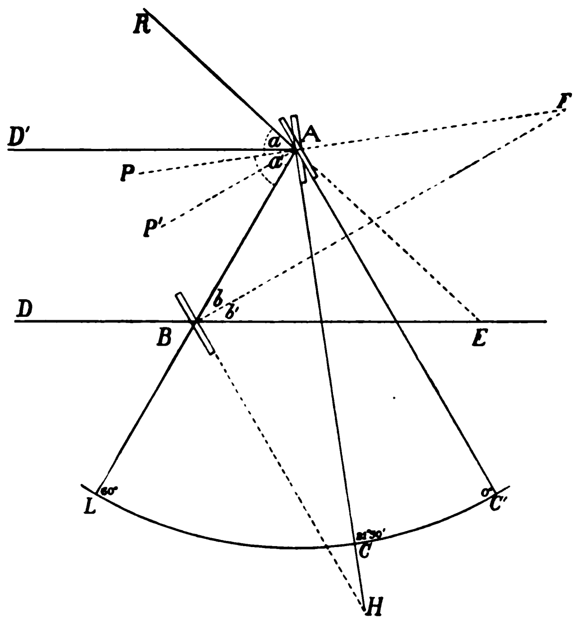

Fig. 2.

The Index Glass, seen to the left of the side opening, answering to *A* in Fig. 2. This glass is pivoted, and to its axis is attached

The Index Arm (*A C*, Fig. 2) at the end of which is a vernier, 30 divisions of which correspond with 29 divisions of the graduated arc (*L* C^1, Fig. 2).

The Graduated Arc, which is of silver, has a radius of $1\frac{1}{8}$ inches and is divided to half degrees from 0° to 140°, and with the vernier consequently reads to single minutes. It will be understood that from the principles previously stated, the arc itself only subtends an angle of 70°, but as according to the law of double reflection stated on page 20, the angle formed by the incident and the reflected rays is equal to twice the angle formed by the mirrors, the divisions of the arc are *numbered* to correspond with the angle subtended by the two objects being sighted.

The Index Glass (and with it the Index Arm) is turned by means of a rack and pinion, which are actuated by the large milled head seen to the right on the face of the instrument. Just below this milled head can be seen in the side opening

The Horizon Glass, (*B*, Fig. 2) which is fixed to the inner framework, but is adjustable by means of three screws, (not seen in the figure,) so that it may be set parallel to the Index Glass, when the index is at zero, and also perpendicular to the plane of the instrument, which, by construction coincides with the plane of the graduated arc, and is per-

pendicular to the axis of the Index Glass. These screws are adjusted by means of a small key with a milled head, shown in the figure to the left of the index arm, and which for security, is screwed into the face of the instrument when not required.

The upper half only of the horizon glass is silvered, so that an object may be seen by direct vision through the lower half, while the reflected image of another object seen in the upper half is brought into coincidence with it by means of the milled head which revolves the index glass.

A Reading Lens, which turns with the index arm, is seen to the left, and allows of the fine graduations of the arc and vernier being easily read.

The heads of two small levers protrude slightly beyond the side of the box, just behind the telescope; these serve to interpose two colored glasses between the two mirrors, which are used when looking at the sun or other bright object, and are lowered into the cover held in the hand when not required. Another colored glass screws on the eye-piece end of the telescope, and is used for the same purpose.

When objects close to are being sighted, the telescope may be found unnecessary; in such case it is replaced by a peep hole sight in a sliding plate, which is passed over the circular hole into which the telescope is screwed, by means of a small stud, shown in the figure to the right of the telescope.

From this description and from the figure it will be seen that the Box Sextant is a very compact instrument, and that the parts most liable to derangement are inclosed in the box and are thus protected from injury. The Box Sextant will, therefore, when once well adjusted, retain its adjustments for months, and even years, without more than the usual care required by all instruments of this class. This property, coupled with the fineness of the readings, and its extreme portability, makes it an instrument of especial value to the Engineer. It must, however, never be forgotten that the angles measured by the Box Sextant (as well as the Sextant) are the angles subtended by two objects in their common plane, and are neither horizontal nor vertical angles unless the plane uniting the objects themselves should be a vertical or a horizontal one. With practice however, the Engineer or Surveyor will find means whereby the angles observed may be reduced to a horizontal or vertical plane, circumstances of position of the objects, or others, helping much the accomplishment of this necessary purpose.

As also previously stated, the fact should not not be lost sight of that the angle measured is the one having its vertex at E, Fig. 2, and that the position of E will vary with the inclination of the two mirrors, that is, with the distance from each other and from the observer of the two objects, being behind the observer for very small angles, and very close to, or within the instrument itself, for large angles.

TABLE OF SLOPES, WITH THEIR EQUIVALENTS IN VARIOUS DESIGNATIONS.

(*Continued.*)

Per Cent.	One in—	Degrees. °	′	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees. °	′	Inches per Yard.	Feet per Mile.
26.79	3.73	**15**	**00**	9.65	1415	38.89	2.57	21	15	**14.00**	2053
27.00	3.70	15	07	9.72	1426	**39.00**	2.56	21	18	14.04	2059
27.78	3.60	15	32	**10.00**	1467	**40.00**	2.50	21	48	14.40	2112
28.00	3.57	15	39	10.08	1478	40.40	2.47	**22**	**00**	14.54	2133
28.67	3.49	**16**	**00**	10.32	1514	**41.00**	2.44	22	18	14.76	2165
29.00	3.45	16	10	10.44	1531	41.67	2.40	22	38	**15.00**	2200
30.00	3.33	16	42	10.80	1584	**42.00**	2.38	22	47	15.12	2218
30.56	3.27	16	59	**11.00**	1613	42.45	2.36	**23**	**00**	15.28	2241
30.57	3.27	**17**	**00**	11.01	1614	**43.00**	2.33	23	16	15.48	2270
31.00	3.23	17	13	11.16	1637	**44.00**	2.27	23	45	15.84	2323
32.00	3.12	17	44	11.52	1690	44.44	2.25	23	58	**16.00**	2347
32.49	3.08	**18**	**00**	11.70	1716	44.52	2.24	**24**	**00**	16.03	2351
33.00	3.03	18	16	11.88	1742	**45.00**	2.22	24	14	16.20	2376
33.33	3.00	18	26	**12.00**	1760	**46.00**	2.17	24	42	16.56	2429
34.00	2.94	18	47	12.24	1795	46.63	2.14	**25**	**00**	16.79	2462
34.43	2.90	**19**	**00**	12.40	1818	**47.00**	2.13	25	10	16.92	2482
35.00	2.86	19	17	12.60	1848	47.22	2.12	25	17	**17.00**	2493
36.00	2.78	19	48	12.96	1901	**48.00**	2.08	25	38	17.28	2534
36.11	2.77	19	52	**13.00**	1907	48.77	2.05	**26**	**00**	17.56	2575
36.40	2.75	**20**	**00**	13.10	1922	**49.00**	2.04	26	06	17.64	2587
37.00	2.70	20	18	13.32	1954	**50.00**	2.00	26	34	**18.00**	2640
37.87	2.64	20	45	13.64	2000	50.95	1.96	**27**	**00**	18.34	2690
38.00	2.63	20	48	13.68	2006	**51.00**	1.96	27	01	18.36	2693
38.39	2.60	**21**	**00**	13.82	2027	**52.00**	1.92	27	28	18.72	2746

Per Cent.	One in—	Degrees. °	Degrees. ′	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees. °	Degrees. ′	Inches per Yard.	Feet per Mile.
52.78	1.90	27	50	**19.00**	2787	**67.00**	1.49	33	49	24.12	3538
53.00	1.89	27	55	19.08	2798	67.45	1.48	**34**	**00**	24.28	3561
53.17	1.88	**28**	**00**	19.14	2807	**68.00**	1.47	34	13	24.48	3590
54.00	1.85	28	22	19 44	2851	**69.00**	1.45	34	36	24.84	3643
55.00	1.82	28	48	19 80	2904	69.44	1.44	34	46	**25.00**	3667
55.43	1.805	**29**	**00**	19 95	2927	**70.00**	1.43	34	59½	25.20	3696
55.56	1.80	29	03	**20.00**	2933	70.02	1.43	**35**	**00**	25.21	3697
56.00	1.78	29	15	20.16	2957	**71.00**	1.41	35	22	25.56	3749
56.81	1.76	29	36	20.45	3000	**72.00**	1.39	35	45	25.92	3802
57.00	1.75	29	41	20.52	3010	72.22	1.385	35	50	**26.00**	3813
57.73	1.73	**30**	**00**	20.78	3048	72.65	1.38	**36**	**00**	26.16	3836
58.00	1.72	30	07	20.88	3062	**73.00**	1.37	36	08	26.28	3854
58.33	1.71	30	15	**21.00**	3080	**74.00**	1.351	36	30	26.64	3907
59.00	1.69	30	32	21.24	3115	**75.00**	1.333	36	52	**27.00**	3960
60.00	1.67	30	58	21.60	3168	75.35	1.327	**37**	**00**	27.13	3979
60.09	1.66	**31**	**00**	21.63	3173	75.75	1.320	37	09	27.27	4000
61.00	1.64	31	23	21.96	3221	**76.00**	1.315	37	14	27.36	4013
61.11	1.64	31	26	**22.00**	3227	**77.00**	1.299	37	36	27.72	4066
62.00	1.61	31	48	22.32	3274	77.78	1.286	37	51	**28.00**	4107
62.49	1.60	**32**	**00**	22.49	3299	**78.00**	1.282	37	57	28.08	4118
63.00	1.59	32	13	22 68	3326	78.13	1.280	**38**	**00**	28.13	4125
63.89	1.57	32	34	**23.00**	3373	**79.00**	1.266	38	19	28.44	4171
64.00	1.56	32	37	23.04	3379	**80.00**	1.250	38	40	28.80	4224
64.94	1.54	**33**	**00**	23.38	3429	80.56	1.241	38	50	**29.00**	4253
65 00	1.54	33	01	23.40	3432	80.98	1.235	**39**	**00**	29.15	4276
66.00	1.52	33	25	23.76	3485	**81.00**	1.234	39	00½	29.16	4277
66.67	1.50	33	41	**24.00**	3520	**82 00**	1.219	39	21	29.52	4330

Per Cent.	One in—	Degrees. °	′	Inches per Yard.	Feet per Mile.	Per Cent.	One in—	Degrees. °	′	Inches per Yard.	Feet per Mile.
83 00	1.205	39	42	29.88	4382	91.67	1.091	42	30	**33.00**	4840
83.33	1.200	39	48	**30.00**	4400	**92.00**	1.087	42	37	33.12	4858
83.91	1.192	**40**	**00**	30.21	4430	**93.00**	1.075	42	55	33.48	4910
84.00	1.190	40	02	30.24	4435	93.25	1.072	**43**	**00**	33.57	4924
85.00	1.176	40	22	30.60	4488	**94.00**	1.064	43	14	33.84	4963
86.00	1.163	40	42	30.96	4541	94.44	1.059	43	22	**34.00**	4987
86.11	1.161	40	44	**31.00**	4547	94.68	1.056	43	26	34.09	5000
86.93	1.150	**41**	**00**	31.29	4590	**95.00**	1.053	43	32	34.20	5016
87.00	1.149	41	01	31.32	4594	**96.00**	1.042	43	50	34.56	5069
88.00	1.136	41	21	31.68	4646	96.57	1.035	**44**	**00**	34.76	5099
88.89	1.125	41	38	**32.00**	4693	**97.00**	1.031	44	08	34.92	5122
89.00	1.124	41	40	32 04	4699	97.22	1.029	44	12	**35 00**	5133
90.00	1.111	41	59	32.40	4752	**98.00**	1.020	44	25	35.28	5174
90.04	1.110	**42**	**00**	32.41	4754	**99.00**	1.010	44	43	35.64	5227
91.00	1.099	42	18	32.76	4805	**100.00**	1.00	**45**	**00**	**36.00**	5280

Intermediate Slopes may be obtained by interpolation.

THE YARD MEASURE AND THE METRE.

THE TRUE EQUIVALENT of the yard measure in terms of the metre is found by Professors Comstock and Tittman of the United States Coast Survey, and by Dr. Peters of Germany, director of the International Committee of Weights and Measures, to be 39.3700 inches. The correction is 0.0008 of an inch, the value found by Kater and Arago in 1818, and in vogue since that year being 39.3708 inches. The corrected measure, 39,3700 inches, will, it is expected, duly become the recognized standard.—*Scientific American.*

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. APRIL 1, 1893. No. 9.

THE SECTOR. III.

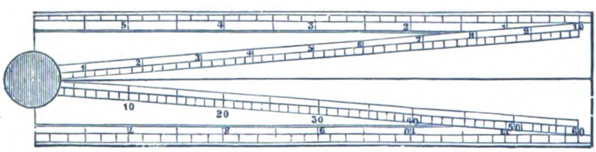

Fig. 1.

3. *To measure an angle B A C, Fig.* 2.

This may be done in several different ways, each of which we shall describe.

First :— With the lines of chords. Take the dividers, and with *A* as centre, lay off on each leg by means of the arc *D G* an equal convenient distance *A D* and *A E*, then open out the Sector until this same distance becomes a transverse distance from 60 to 60 on the lines of chords. Now take in the dividers the chord of the angle from point to point just laid off on the sides, *i. e. D E*, and apply this distance transversally to the lines of chords on the Sector, when the reading on each leg will be the number of degrees in the angle sought for.

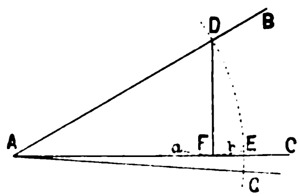

Fig. 2.

Second:— With the lines of sines. Lay off a convenient distance on *A B* from *A*, say *A D*, and from *D* draw *D F* perpendicular to and intersecting *A C* in *F*. Now with the dividers make *A D* a transverse distance from 90 of one line of sines to 90 of the other line of sines, then take in the dividers the perpendicular *D F* and apply it transversally to the lines of sines on the Sector, when the coinciding points on each leg will be the number of degrees in the angle *B A C*.

Third:— With the lines of tangents. Lay off a convenient distance on *A C* from *A*, say *A F*, and erect upon *A C* the perpendicular *D F*. Now with the dividers make *A F* a transverse distance between 45 of each line of tangents on the sector, then take in the dividers the length *D F* and apply it transversally to the lines of tangents until similar points on each line are found which take in between them exactly this distance *D F*; the readings of these points will be the number of degrees in the angle *B A C*.

In these examples it must be distinctly borne in mind that a transverse distance means a distance from a given number on one leg to the *same* number on the other leg. All transverse distances will therefore be lines parallel to *D E*.

From a slight examination of the sector it will be seen that for angles greater than about 70°, some indirect method of measuring an angle must be followed. In this, as in other cases, where the simple measurement of the angle is required, irrespective of any of its trigonometrical functions, the lines of chords will be found to be the most suitable to use, as the differences between successive degrees are much more uniform than is the case with either the sines or the tangents of the angles. If, therefore, we wish to measure an angle of what we should suppose to be about 150°, we should consider the simplest method would be with the lines of chords, to continue one side of the angle beyond the point of intersection, and then to measure the small angle thus laid down and deduct it from 180°, which would then give the value of the larger angle. If we wished to measure an angle of say about 100°, we should first strike a convenient arc intersecting the sides of the angle and measure off 60° with the same diameter upon this arc; then measure in the manner described the remaining angle, which, added to 60° will give the total angle.

To measure very small angles, say less than 5° or 10°, proceed as above, and deduct the value of the larger from 60°, when the remainder will be the number of degrees in the smaller angle.

Fourth:— To protract an Angle. Let it be required to protract an angle of 25° upon *A C*. Take in the dividers any convenient length, say

$A\ E$, and describe with A as centre the arc $D\ G$, then make this same length a transverse distance between 60 and 60 of the lines of chords. Now take in the dividers the transverse distance between 25 and 25, and with E as centre describe a small arc cutting $D\ G$ in D, and join $A\ D$, then the angle $D\ A\ E$ will be the required angle of 25°. By similar methods, and noting the directions already given for measuring angles, any required angle may also be protracted by means of the scales of sines and tangents. In those cases where it is required to know the sine or the tangent of an angle, the lines of these functions will be used instead of the lines of chords; thus, let $A\ D$ to a convenient scale $= 150$, and let it be required to obtain the sine of an angle at A of 25° to radius 150. Make $A\ D$ a transverse distance between 90 and 90 of the lines of sines, then take in the dividers the transverse distance 25, and with this as radius and D as centre, describe the small arc $a\ b$, and draw $A\ F$, and $D\ F$ perpendicular to $A\ F$; then will the angle $D\ A\ F = 25°$, and $D\ F$ will be the sine of the same to radius $A\ D$, while $A\ F$ will be the sine of $A\ D\ F = 65°$ to the same radius. On measuring $D\ F$, it will be found $= 63\ +$, while sine $25° \times 150 = 63.4$.

Fifth:—To construct a regular polygon. This is of course the same as dividing the circumference of a circle into a given number of equal parts. As the radius of a circle and the side of an inscribed regular hexagon are equal, the legs of the Sector must be opened out until the radius of the circle becomes a transverse distance between 6 and 6 of the lines of polygons; then take in the dividers the transverse distance corresponding to the number of sides the required polygon is to have, and with this opening prick off on the circumference of the circle the given number of equal parts; join these points by straight lines, and the polygon is complete.

If it should be required to construct, say a heptagon, upon a given straight line, first take in the dividers the length of the line and make it a transverse distance between 7 and 7 of the lines of polygons, then take in the dividers the transverse distance 6 to 6, and with this as radius describe a circle whose circumference shall touch each end of the given straight line, then with the dividers transfer the length of the straight line round the circumference when it will be found to have been divided into 7 equal parts.

Regular polygons may also be constructed by means of the lines of chords, by dividing 360° by the required number of sides, then finding the chord of the centre angle to a given radius, and pricking off this chord round the circumference of a circle, described with the given radius.

ADJUSTMENTS OF SURVEYING INSTRUMENTS. VI.

THE TRANSIT.

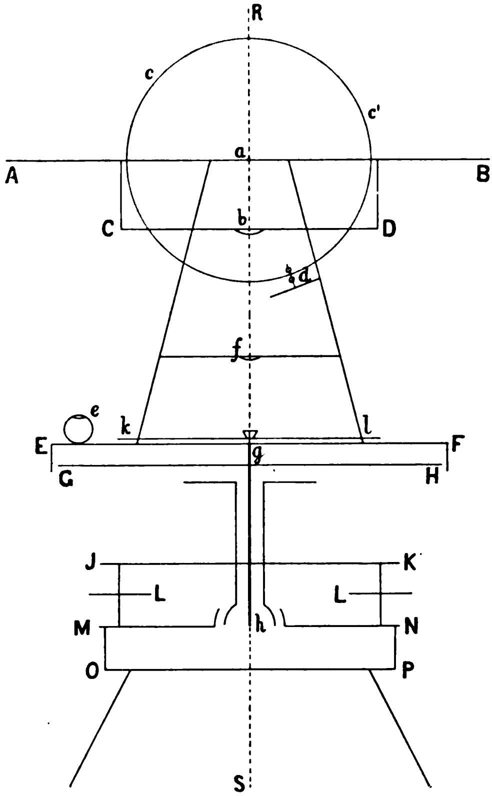

Fig. 1.

WE NOW COME to the adjustments of the Engineer's Transit. Let Fig 1 be a linear diagram showing the axes and the planes of its principal parts, some of which are adjusted by the maker as a necessary detail of construction, while the others require attending to by the operator himself.

In the figure the following parts are shown, viz:—

A B = Telescope Optical Axis and Line of Sight or Line of Collimation;

a = Centre of Axis of revolution of the telescope;

C D = Telescope Level Tube, with

b = Centre of Bubble in the centre of its run;

$c\ c^1\ d$ = Vertical Limb or Arc, with
d = Vernier for reading same;
$E\ F$ = Top of Vernier Plate, with
e, f = Bubble Tubes on the Top Plate and one on pair of Standards;
$G\ H$ = Horizontal Limb;
$J\ K$ = Upper Leveling Plate or Patent Leveling Arms;
$M\ N$ = Tripod Plate, with
$L\ L$ = Leveling Screws;
$O\ P$ = Tripod Head;
$g\ h$ = Spindle or Inner Centre;
$k\ l$ = Compass Needle;
$R\ S$ = Vertical Axis passing through the centre of the Spindle and the axis of revolution of the Telescope a.

In the case of the Transit, as of the Level, the basis of all adjustments and operations is the imaginary vertical line $R\ S$, which is to be brought into coincidence with the earth's radius upon which the operator is located. As the Transit is used for measuring both horizontal and vertical angles, and these latter even when subtended by objects in different horizontal planes, by referring the vertical angle to the horizon, it is evident that the adjustments of the Transit will differ from those of the Level. The Transit may be said, therefore, to be composed of the following main parts, to which all others are subservient, viz:—

A vertical axis forming one continuous straight line (in part real and in part imaginary) from R to S.

A horizontal graduated limb $G\ H$, capable of circular motion around $R\ S$.

A revoluble telescope, whose optical axis and line of collimation coincide, and are shown by $A\ B$.

A vertical graduated limb $c\ c^1\ d$, attached to the telescope axis of revolution, and revolving with it.

If we now suppose that $R\ S$ is perfectly vertical, it is necessary in a well made and perfectly adjusted Transit that the following conditions should exist.

The horizontal limb $G\ H$ must be perpendicular to $R\ S$, however it be revolved upon $R\ S$. It may be as well to state here that in this connection we mentally include the top plate $E\ F$ with the horizontal limb, as it is also capable of circular motion around $R\ S$, and as the telescope standards rest upon it, it becomes an indispensable part of the vertical $R\ S$. The horizontality of $G\ H$ is determined by the level bubbles e and f.

The telescope axis of revolution must be perfectly perpendicular to

R S, parallel to *G H* and *E F*, and perpendicular to the optical axis and line of collimation; further, when *A B* is horizontal, as shown by the bubble *b* being in the centre of its run, then *A B* should be perpendicular to *R S*, however much the telescope, with the standard and the top plate (clamped to the horizontal limb or not) be turned round upon *R S*, or in *azimuth*, as it is termed. If these conditions exist, then, when the telescope is revolved upon its horizontal axis, or in *altitude*, the line of collimation will at all times be in the planes *R S* and *A B*.

The vertical limb $c\ c^1\ d$ is attached to the telescope axis, and should be perpendicular to it, and the vernier *d* so adjusted that when the line of collimation is horizontal, as indicated by the bubble *b* (the axis *C D* of this bubble tube being parallel to the line of collimation) the zero of the vertical limb and the zero of the vernier shall coincide. By this means vertical angles of elevation or depression may be at once read off on the vertical limb.

Some of these essential conditions are necessarily carried out by the maker during the process ot construction, while others require to be effected by the Engineer, more or less frequently, facilities of adjustment of certain parts being always provided. As in the case of the Level, we also rely for the Transit mainly upon the level tubes and the principle of reversion to ascertain the horizontality and verticality of the different parts, although as in the latter instrument the telescope is not reversible, but its axis of revolution is fixed in the standard, we are obliged to have recourse to a somewhat different mode of operation, which will be fully described in future articles. What conditions are, however, essential to correct work, will, we think, have been already made sufficiently clear.

THE BUBBLE, THE VERNIER AND THE TELESCOPE.

WE ARE LED, in consequence of certain circumstances which have lately come under our notice, to state as briefly as possible what we conceive to be the correct view of the relationship which should exist between the above parts of surveying instruments.

We stated in a former number, (Vol. I. p. 106) when describing the Transit, that the sensitiveness of the spirit level should be in proportion to the accuracy and care bestowed upon the construction of the instrument, to the magnifying power of the telescope, and to the fineness of the graduations of the limb (read by the vernier).

There should always be a correlation between these parts, as will be evident if we consider the following points.

1. If the telescope of a Transit is turned *very slightly* upon its ver-

tical axis by means of the tangent screw of the top plate, and if such difference of position is perceptible by reason of the altered position of the cross hairs, in relation to the object sighted, the graduations of the limb and vernier should be such that it is possible at least to estimate, if not actually to read by means of the vernier, the amount of this displacement. Should on the other hand, the slight movement given to the telescope not be rendered perceptible by means of the cross hairs, then a finely divided limb and vernier are worse than useless; hence, the magnifying power of the telescope and the least count of the vernier should be mutually proportionate.

2. Suppose, having set up a Level and carefully adjusted it by means of the leveling screws, and that, while taking an observation we disturb it, by accidentally touching one of the tripod legs, and that this disturbance, although very slight, is perceptible, owing to the visibly altered position of the cross hairs on the rod, but that we find on examination of the bubble no evidences of a change of level in the instrument: —of what use, we ask, is an instrument with such a level tube? Clearly its sensitiveness is not proportionate to its magnifying power. And yet we sometimes hear of demands for a telescope with high magnifying power and a bubble that *settles quickly*. It must be evident that in such a case the telescope may be 1 or 2 minutes out of the horizontal without the surveyor being aware of the fact, and this may mean an error of 2 or 3 feet in a mile. On the other hand, if the sensitiveness of the level is greater than the magnifying power of the telescope, waste of time and need of considerable patience will be natural consequences; but a delicate bubble, which registers very slight variations of level, will undoubtedly give closer actual results than a sluggish bubble which indicates a level which is not a true one. The same remarks apply equally to the plate levels and to the telescope level of a Transit.

To sum up:—The Bubble, the Vernier and the Telescope should be correlated, and also be proportionate to the work to be done; if however there is any disproportion, it should be carefully seen that it is on the part of the bubble, as the results obtained cannot at least be in any way vitiated by this circumstance.

The above remarks are based on the assumption that the workmanship and care bestowed upon the construction of the instruments are all that could be desired, otherwise no reliance could be placed upon the results obtained, however well proportioned the main parts here referred to may be.

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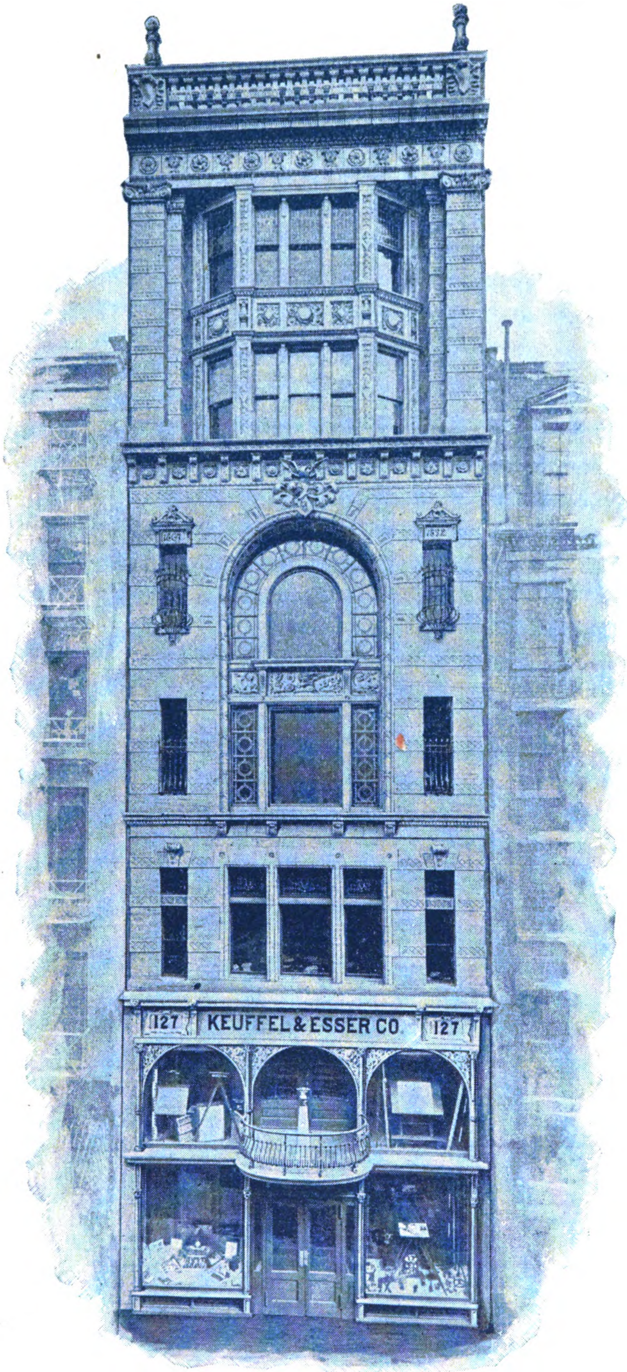
All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

WE MENTIONED in our last that Keuffel & Esser Co., the publishers of THE COMPASS had taken possession of their new premises. We present to our readers in this number a front view (Fulton Street) of the building in which THE COMPASS now has its home, and which, it is allowed by all who have seen it, reflects great credit upon the architects, Messrs. Delemos & Cordes, of this city, both as regards its external beauties and its internal arrangements.

The area covered being 118 feet by 25 feet, and the building eight stories high, our readers will be enabled to form some idea of the requirements of their growing business and of the facilities they have been compelled to provide themselves with to enable them to meet these requirements.

We may be allowed to state in conclusion that the success attained in the past is the result of an honest desire to serve every client well and promptly, and that this policy will continue to guide the firm in all its future transactions.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ON THE USE OF LONG STEEL TAPES IN MEASURING A BASE LINE.

REPORT OF U. S. C. AND G. SURVEY.

AT THE Rochester Meeting of the American Association for the Advancement of Science, Mr. R. S. Woodward of Washington, D. C., described a method of standardizing steel tapes by means of an iced bar comparator. The iced bar employed in the comparator consists of a bar of steel, on which are lines five metres apart, at a temperature of 32 degrees Fahr. To preserve the bar at this temperature it is surrounded by ice. The whole is mounted on a carriage that travels on a small railway. In measuring off the length of the comparator, which in most cases was 100 metres, the cross hairs of two microscopes were first made to coincide with the lines on the bar. The bar was then moved forward, and the mark on the end nearest the starting point placed under one of the set microscopes. A third microscope was then set over the end away from the starting point. The microscopes were mounted on wooden posts. At the ends of the comparator two stones are solidly embedded in the earth. In each of these stones a rounded brass projection is imbedded, to mark the ends of the comparator. To place the microscopes directly over these end points a special device containing a level is used. Having obtained the proper setting of two microscopes that are the length of the comparator apart, the tape is held under them in a way that was found to be the most convenient and reliable in field work. Stakes are set ten metres apart along the line to be measured, and in the side of these round steel wire nails are driven. The tape is supported on these nails. The corrections necessary to apply, if the posts are set at a greater distance, as in crossing a stream, can be easily computed from data furnished by preliminary experiments. The tension of the tape was made the same, about 25 pounds in all measurements, by means of a spring balance at one of its ends, a breaking piece being inserted, so that by no means could the operators overstrain the tape. Temperature observations were made in each case, three special thermometers being used with blackened bulbs, so that the surface had approximately the same radiating power as the tape.

It was proved by the comparator that, with ordinarily careful handling, there was no variation in length of the 100 metre tapes after long use. To test the efficiency of the steel tapes when used in the field, a Kilometre was measured by means of the iced bar, and this Kilometre used as a standard. It was found that the probable error of a single measurement of this Kilometre by means of the steel tapes was about one part in 500,000, and that the probable error of the average of a number

of observations was about one part in 1,500,000. So that the general conclusion arrived at is, that for measuring base lines, steel tapes, as standardized by the iced bar comparator, will give ample accuracy. The time required to make duplicate measures of the Kilometre with the tapes is about one hour, and in special cases it was measured in one direction in twenty minutes. The method of measuring the standard Kilometre by means of the iced bar apparatus, and probable error of the total length, was given in another section of the society, but as it is of interest in connection with the present paper, the following table is here given, which compares the probable errors involved, with the results obtained by previous workers in the same line:—

PROBABLE ERROR IN MEASURING A KILOMETRE.

Best work of Lake Survey	$\pm$ 0.40 m/m
Recent work of French on Paris and Perpignan base	$\pm$ 0.67 m/m
Best work of iced bar:	
1st. On comparator	$\pm$ 0.10 m/m
2d. On Kilometre	$\pm$ 0.12 m/m

This table shows that the error in the work done with the iced bar is about one-quarter that of any other method previously adopted.

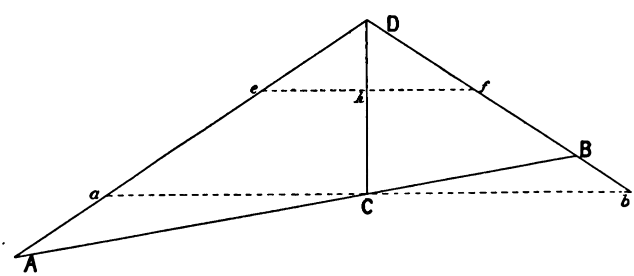
The greatest source of error was found to be the difficulty of determining the temperature of the tape correctly. It is generally supposed that a cloudy day is preferable for measuring with steel tapes, but the experiments indicated that such was not the case. The best time was found to be in the evening, while dew was being deposited.—*American Machinist.*

ON CALCULATING QUANTITIES.

COMMUNICATED BY CHAS. S. YOUNG, BOG WALK, JAMAICA.

THE FOLLOWING NOTES on the use of the Slide Rule for the purpose of calculating quantities on estimates and balancing cuts and fills on profiles may be useful to some of your readers.

In the last few numbers of THE COMPASS the equivalent angular readings for slope ratios have been given. i. e. $\frac{1}{8}$ to 1 = 7° 08′. $\frac{1}{4}$ to 1 = 14° 02′; $\frac{1}{2}$ to 1 = 26° 34′; 1 to 1 = 45°; 1$\frac{1}{2}$ to 1 = 56° 19′.



Let $A\ D\ C$ and $B\ D\ C$ be such angles, $A\ B$ or $a\ b$ being the natural slope of the ground, and let $D\ C$ bisect the angle $A\ D\ B$, and be equal to 1 foot.

By varying the slope of $A\ B$, we may calculate the areas of the different triangles by the formula

$$\text{Area} = \frac{1^2 \times \sin DCA \times \text{Sin } A\ D\ C}{2 \times \sin D\ A\ C}$$

and tabulate the results thus :—

TABLE I.

Angle.	$\frac{1}{8}$ to 1	$\frac{1}{4}$ to 1	$\frac{1}{2}$ to 1	1 to 1	$1\frac{1}{2}$ to 1
0°	0.062 0.063 } 0.125	0.125 0.125 } 0.250	0.250 0.250 } 0.500	0.500 0.500 } 1.000	0.750 0.750 } 1.500
5	0.063 0.062 } 0.125	0.128 0.123 } 0.251	0.261 0.240 } 0.501	0.548 0.459 } 1.007	0.864 0.663 } 1.527
10	0.064 0.061 } 0.125	0.131 0.120 } 0.251	0.274 0.230 } 0.504	0.606 0.425 } 1.031	1.020 0.592 } 1.612
15	0.065 0.061 } 0.126	0.135 0.117 } 0.252	0.290 0.221 } 0.511	0.682 0.395 } 1.077	1.254 0.533 } 1.787
20	0.066 0.060 } 0.126	0.138 0.115 } 0.253	0.307 0.213 } 0.520	0.788 0.367 } 1.155	1.662 0.487 } 2.149
25	0.066 0.060 } 0.126	0.142 0.112 } 0.254	0.327 0.204 } 0.531	0.937 0.342 } 1.279	2.510 0.442 } 2.952
30	0.067 0.059 } 0.126	0.146 0.109 } 0.255	0.352 0.195 } 0.547	1.183 0.316 } 1.499	5.630 0.403 } 6.033
35	0.069 0.058 } 0.127	0.152 0.106 } 0.258	0.385 0.186 } 0.571	1.667 0.294 } 1.961	
40	0.070 0.057 } 0.127	0.159 0.104 } 0.263	0.431 0.176 } 0.607	3.118 0.273 } 3.391	
45	0.072 0.055 } 0.127	0.167 0.100 } 0.267	0.502 0.168 } 0.670		
50	0.074 0.054 } 0.128	0.177 0.096 } 0.273	0.619 0.157 } 0.776		
55	0.076 0.053 } 0.129	0.194 0.092 } 0.286			
60	0.080 0.051 } 0.131	0.220 0.087 } 0.307			

The volume of a prism 100 feet long, whose cross section is composed of the two triangles $A\ D\ C$ and $B\ D\ C$, would be the sum of the areas of the respective triangles $\times$ 100 $\div$ 27, and may be also tabulated as follows :—

TABLE II.

Angle.	$\frac{1}{8}$ to 1	$\frac{1}{4}$ to 1	$\frac{1}{2}$ to 1	1 to 1	$1\frac{1}{2}$ to 1
0	0.46	0.93	1.85	3.71	5.56
5	0.46	0.93	1.86	3.73	5.65
10	0.46	0.93	1.87	3.82	5.97
15	0.46	0.93	1.89	4.00	6.62
20	0.46	0.94	1.93	4.28	7.97
25	0.46	0.94	1.97	4.82	10.92
30	0.47	0.95	2.02	5.56	22.33
35	0.47	0.96	2.12	7.27	
40	0.47	0.97	2.25	12.56	
45	0.47	0.99	2.48		
50	0.47	1.01	2.88		
55	0.48	1.06			
60	0.49	1.14			

If we now make $A\ B$ horizontal, and a given length, say the usual widths of road beds as $e\ f$ we may calculate the corresponding heights of $D\ h$, and also the volume of grade prisms $D\ e\ f$, 100 feet long, having those end areas, and tabulate the results thus:

TABLE III.

Width Road-bed ef	$\frac{1}{8}$ to 1		$\frac{1}{4}$ to 1		$\frac{1}{2}$ to 1		1 to 1		$1\frac{1}{2}$ to 1	
	$D\ h$	Vol.	$D\ h$	Vol.	$D\ h$	Vol.	$D\ h$	Vol.	$D\ h$	Vol.
12 ft.	48.0	1066.7	24.0	533.3	12.0	266.7	6.0	133.3	4.0	88.7
14 "	56.0	1451.8	28.0	725.9	14.0	362.9	7.0	181.5	4.7	121.8
16 "	64.0	1896.3	32.0	948.2	16.0	474.1	8.0	237.0	5.3	157.0
18 "	72.0	2400.0	36.0	1200.0	18.0	600.0	9.0	300.0	6.0	200.0
20 "	80.0	2963.0	40.0	1481.5	20.0	740.8	10.0	370.4	6.7	248.2

The application of these tables to practical use is briefly as follows, being based on the proposition that the areas of similar triangles are to each other as the squares of their homologous sides, thus,

$$\text{Area } A\ D\ B : \text{area } A^1\ D^1\ B^1 = (D\ C)^2 : (D^1\ C^1)^2$$

Example. Let $A\ e\ f\ B$ represent the cross section of a fill, in which Roadbed $e\ f = 18$ ft; Side Slopes $= 1\frac{1}{2}$ to 1; Fill or centre height $h\ C = 7$ ft; Slope of ground $= 15^\circ$, — required the cubic yards in 100 feet length.

We have from Table III, Depth of fill 7 ft. + height $D\ h$ 6 ft. = 13 feet, then by Table II, under Slope $1\frac{1}{2}$ to 1 and opposite 15°, $13 \times 13 \times$

6.62 = 1119 cubic yards = contents of triangular prism $A\ D\ B$. Now from Table III we see that the contents of the grade prism $D\ e\ f = 200$ cubic yards, therefore, contents of the prism $A\ e\ f\ B = 1119 - 200 =$ 919 cubic yards.

The working out of this on the Slide Rule is exceedingly simple, thus

A		Find 1119 c. yds.
B		Over 6.62 (from Table II).
C	Set 1	
D	Over $7 + 6 = 13$	

then 1119 — 200 (Table III) = 919 cub. yards.

The few figures required from Table III are easily memorized, and the addition of the fill and the grade prism centre height performed mentally.

I find that my best results come from using readings every 50 feet and halving the final results, counting the number of operations and making only one subtraction for the grade prism.

I have given Table I for the benefit of those cases where it is thought to be better to use three level sections, to construct a table of coefficients similar to those in Table II.

As to the results obtained by this method, I once estimated twelve miles of heavy ragged work by it, and on cross-sectioning found the results to be within a few per cent. I will also undertake with readings of 50 feet to do eight miles a day on the slide rule, whereas three miles with tables is considered good work.

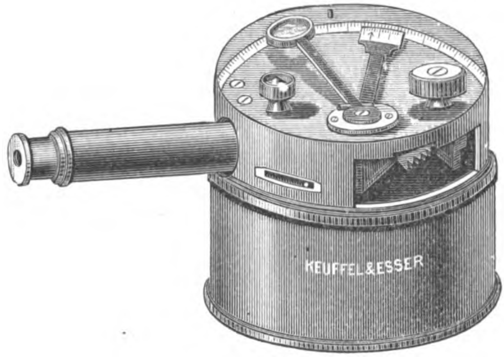
LIGHT: ITS REFLECTION AND REFRACTION. VII.

THE BOX SEXTANT.

WE STATED in our description of the Box Sextant that the Horizon Glass is fixed to the inner framework of the box, but is adjustable by means of three screws.

A plane passing through the axis of the Index Glass is the basis of the construction and of the adjustments of the Sextant, while another plane, perpendicular to this axis, is called the *plane of the instrument*, and is, or should be, coincident with its upper face and with the graduated arc, the index glass being then perpendicular to both. This important point is supposed to be always attended to by the maker. Assuming such to have been the case, we in the first place examine the horizon glass to see if it is also perpendicular to the plane of the instrument, and secondly to determine if there be any index error, that is, we must ascertain if,

when the vernier zero, or the *index* as it is called, is set to zero of the arc, the direct and reflected images of a distant object coincide perfectly. The adjustment of the horizon glass is effected by means of the two square headed screws upon the face of the instrument just behind the large milled head by which the index glass is turned upon its axis, while the index error is corrected by means of a similar screw in the side of the box below the two screws in the face.



To ascertain if the horizon glass is perpendicular to the plane of the instrument, take the sextant in the left hand, and after setting the index to zero, hold it vertically and look at some clear well defined perpendicular line, and if, as the index is moved gently to the right and to the left of zero of the arc, the direct and the reflected images seem to form one single and unbroken straight line, then the instrument is in adjustment. Now hold the instrument horizontally, and set the index to make the direct and reflected images of a well defined perpendicular line coincide, then move the sextant gently up and down so as to take in the line from the top to the bottom, and if it appears perfectly straight and does not present a wavy or undulating appearance, the glasses are in adjustment. Should either of these methods reveal any irregularity in the lines, then the horizon glass must be adjusted by means of the key provided for the purpose, and screwed into the face of the instrument when not in use, until the conditions stated are fulfilled. Should it be found impossible to obtain satisfactory results by means of the second test, it is then very probable that the index glass is not perpendicular to the plane of the instrument, which defect can only be remedied by the maker.

It will be seen that the arc is graduated for a few degrees to the left of zero; these extra divisions are what are called the *arc of excess*, and serve to ascertain the index error in the most reliable manner. The method generally adopted is as follows:—

Hold the instrument vertically in the right hand and sight directly the lower limb of the sun, then with the left hand turn the large milled head

until the reflected image of the sun's upper limb coincides with his lower one, and take note of the exact reading. Now sight directly the upper limb of the sun and with the left turn the index until the reflected image of the sun's lower limb coincides with his upper limb, and again note carefully the reading. In the first case this reading will be on the arc of the instrument to the right of zero, and in the second case on the arc of excess to the left of zero. If these two readings are the same, the index is in adjustment, but if they differ, then half their difference represents the correction to be applied to all observations, the correction being added, when the reading on the arc of excess is the greater, and subtracted when the reading on the arc of the instrument is the greater; thus, if

the reading on the arc of the instrument be	28′
and " " " excess be	36′
Difference =	8′

and the constant or index error is 4 minutes which must be added to every reading. The measurement of the sun's apparent diameter is half the sum of the two readings. Having discovered the error it is advisable to remove it by means of the key and square headed screw already referred to. It is not essential that these readings be taken with the sun, as this method can be followed with any other object (at least half a mile distant) such as a house with clearly defined vertical sides. It is needless to say that when measuring the sun's apparent diameter, the colored glasses should be used, both between the two mirrors and on the telescope.

A rapid means of adjustment of the index is to bring both zeros into coincidence, and then by means of the key and the screw in the *side* of the box adjust the horizon glass so that the direct and the reflected images of a distant perpendicular line coincide.

The Sextant is sometimes provided with a Prismatic Compass, the needle box being sunk in its face. The combination is so arranged that the free and independent use of each instrument is not interfered with, while the sight enables azimuthal angles of objects not in the same horizontal plane, to be very much more easily obtained.

As the vernier of the Sextant reads to single minutes, it is evident that it must prove a most useful instrument for the Surveyor or Engineer, especially as with care and practice, results approximating even those of the transit may be obtained.

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. MAY 1, 1893. No. 10.

THE HELIOGRAPH.

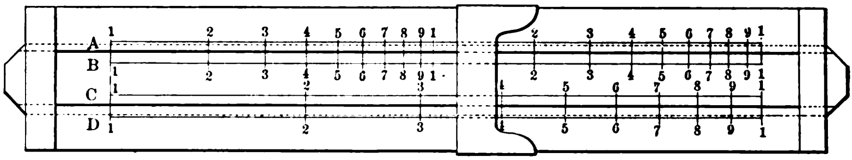
SOME INTERESTING experiments were made a short time ago to place the cities of New York and Brooklyn in communication with each other by means of the Heliogragh. Captain E. B. Ives, signal officer of the First Brigade of the National Guard of this State, and Corporals Butler and Fones and Private Samson of the Signal Corps, stationed themselves upon the top of the Western Union Building, in New York, while a squad from the Second Brigade occupied the top of the Franklin Trust Building in Brooklyn.

These experiments were so satisfactory that Captain Ives will apply for permission to erect a permanent station on the Western Union Building, while other stations will be arranged for in Brooklyn, El Dorado, Staten Island and on the Orange Mountains.

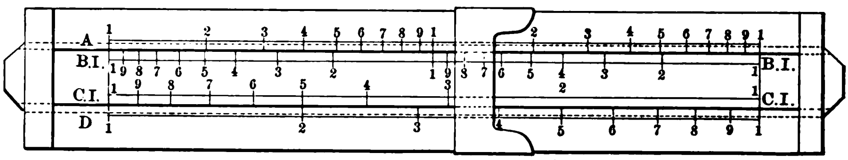
As the Heliograph in its simpler form, (then called a Heliotrope) is often used in geodetic surveying, a description of the instruments used in the above experiments will probably interest some of our readers; we shall therefore devote an article in our next number to their consideration.

THE DUPLEX SLIDE RULE.

Patented October 6th, 1891.



Front or Upper Face.



Back or Under Face.

MANY FORMULÆ in Practical Mathematics, Mechanical and Civil Engineering take the form of

$$a \times b \times c = x.$$

The solution of this formula can only be obtained with the ordinary or Mannheim Slide Rule by means of three operations, thus

C	Set 1	Runner to b	1 to Runner	Under c
D	To a			Find x

To do away with this really needless labor, we have designed the "DUPLEX" SLIDE RULE, of which the above figures represent the upper and under, or front and back faces. This new Slide Rule is similar to an ordinary Mannheim, the difference being that the slide itself is of the same thickness as the rule, and has consequently its two faces flush with those of the rule. Both sides of the slide are graduated, the graduations of the rule, that is, scales A and D being *alike on both faces*, while the scales B and C of the slide are graduated on the upper face in the usual way, like A and D, but on the under face in *reversed order*, the initial indices being on the right hand, and the scales progressing towards the left. These reversed lines of graduations are equivalent to *inverting* the slide itself, but possess many advantages which will be at once apparent. The right and left indices of the four different scales on the reversed or under face of the rule coincide with those of the scales on the ordinary or upper face, and a metallic runner, encircling the whole rule, enables coinciding points on any scale of either face to be at once found.

Without mentioning all the advantages obtained by means of this new construction, we may state that the inverted scales B and C lie alongside of their corresponding scales A and D, so that settings and readings are as easily effected and noted as with the slide in its ordinary position. Those in the habit of using the slide rule and knowing the special uses of the inverted slide, will certainly appreciate this improvement, and will at once see the many and important advantages to be obtanied from this new arrangement. We shall, however, to enable the merits of the "DUPLEX" to be more easily appreciated, give a few practical examples, which for this purpose will be better than any long explanation.

1. *To find the Area of a Circle, on scales C and D.*

Formula is, Area $= d \times d \times 0.7854$

which we demonstrate thus:

C. I.	Set d	C.	Under d
D	To 0.7854	D	Find Area.

Here there is one single operation performed to obtain the product of three factors. We set on the *under* face the diameter of the circle on C. I. to the constant 0.7854 on D, then turning the rule over, we at once, without any further operations, find on the *upper* face the area on D under the diameter on C.

The cube of a number is obtained on scales C and D in the same manner.

2. *Diameters and Revolutions of Wheels.*

We have in all cases of wheels

Diameter Driving $\times$ Revolutions Driving $=$ Diameter Driven $\times$ Revolutions Driven.

This is worked out entirely on the under face, thus:

C. I.	Set Diam. Driving	Under Diam. Driven
D	To Revs. Driving	Find Revs. Driven.

3. *Required the diameter of a pulley and the number of revolutions per minute which will give a belt speed of* 250 *feet per minute.*

C. I.	Set 250 feet	Under 13 inches	or under 18 inches
D	To G.P. 3.82	Find $73\frac{1}{2}$ revs.	Find 53 revs.

and similarly, all coinciding numbers on C. Inverted and on D give, the former—diameters, and the latter—revolutions, all producing the required belt speed of 250 feet per minute, so that the engineer has but to choose the most suitable combination.

And lastly, we may add that one and the same setting, and one single operation, give the square, the cube, the fourth, fifth and sixth powers of a number, as also the square root of the fifth power.

A duplicate or trigonometrical slide is supplied at a small extra cost, when desired, having on one face the ordinary scales B and C, and on the other face, scales of Sines, Tangents and equal parts. By turning over the rule, as explained, such formulæ as $\frac{b \times c \times \text{Sin A}}{2}$ giving the area of a triangle can be very quickly worked out, and that without the inconvenience of having to take out the slide and reverse the faces as is necessary with the ordinary Slide Rule.

Fuller particulars, as well as the practical solution of some 50 formulæ and problems are contained in THE "DUPLEX" SLIDE RULE, a Manual by the inventor, (William Cox) just published by Keuffel & Esser Co. For price, etc., see back cover of present issue.

LIGHT: ITS REFLECTION AND REFRACTION. VII.

THE GENERAL PRINCIPLES of construction of the ordinary Sextant, more especially used for nautical purposes, are the same as those of the Box Sextant; we shall not therefore describe this instrument here, but at a future time devote a special article or articles to its consideration.

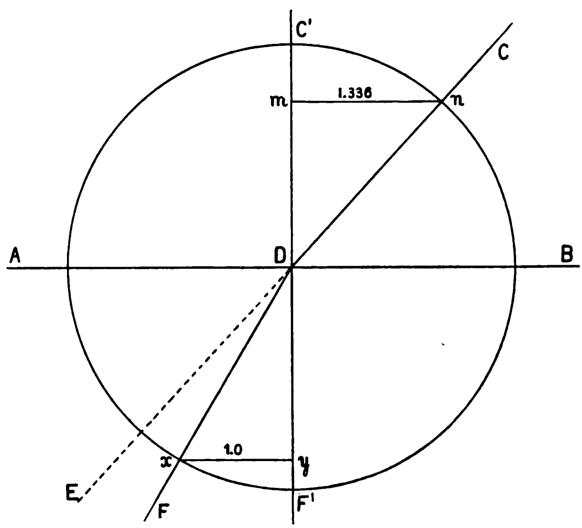
Besides the different instruments already described, illustrating the practical application of the laws of reflected light, several others, embodying the same laws, have been invented, most of them having for their object the determination of ranges and curves. We purpose describing some of these separately in future issues, and now come to the consideration of the second division of our subject, namely

THE REFRACTION OF LIGHT.

If a straight rod be held in a slanting direction in a vessel containing water, it is at once evident to the eye and needs no demonstration, that the direction of the rod appears to change from the surface of the water downwards. Many physical experiments might be described to illustrate this and similar facts, but as they are well known to our readers, we shall not dwell upon them, but proceed to examine the principles which govern this peculiar optical effect termed *refraction*, and their practical application to scientific purposes.

The law of refraction may be briefly stated as follows:—*Rays of light change their direction when they enter obliquely a medium of a different density from the one whence they have emanated.*

This change of direction of a ray of light is not by any means uniform, but varies with the medium and with the ray's obliquity, thus with alcohol it is greater than with water, and in the case of glass it is greater than with either water or alcohol. The amount of the change of direction, or the deviation of a ray of light from a continuous straight line, produced by a given medium is termed the *refractive power* of the medium, and scientists have by means of careful experiments ascertained the refractive power of a great number of media*, and classified them, assigning to each one its own separate *index of refraction*. We shall show graphically how this index is obtained, but without describing the experiments, as it is well to have some idea of what is meant by the index of refraction before proceeding to the examination of refraction as it affects prisms and lenses.



Let, in the figure, $A\ B$ be the separating line between two media, say air above and water below, and let C^1D be a ray of light which strikes the water at D, the direction of the ray C^1D being perpendicular to the surface of the water $A\ B$. Such a ray, striking the water *perpendicularly*, will continue its course in the same straight line and proceed towards F^1. Now let $C\ D$ be another ray of light, proceeding from C and striking the surface of the water *obliquely* at D. This ray, instead of continuing its course in the straight line $C\ D\ E$, will be found to deviate at D, and proceed in the direction $D\ F$. The amount of this deviation

---

* *Medium in optics is any transparent substance which allows a greater or lesser portion of the rays of light falling upon it, to pass through it.*

will, as already stated, vary according to the medium which the ray traverses. In the case before us, where we suppose the upper medium to be air, and the lower medium to be water, it has been found that $D\,n$ and $D\,x$ being the same length, if $x\,y$ measures by any convenient scale 1 unit, then $m\,n$ will measure 1.336 such units. Now it is evident, that $m\,n$ is the sine of the angle $C\,D\,C^1$, and $x\,y$ is the sine of the angle $F\,D\,F^1$, and that the ratio of $x\,y$ to $m\,n$, that is, the ratio of the sine of the angle of refraction to the sine of the angle of incidence, is as 1 is to 1.336. This number 1.336 is therefore called the index of refraction of water.

It is well to note here that the index of refraction does not denote the ratio of the *angle* $F\,D\,F^1$ to the *angle* $C\,D\,C^1$, but the ratio of the *sine* of one angle to the *sine* of the other angle. Let, for example, the angle $C\,D\,C^1 = 20°$, whose sine is 0.342, then we have

1.336 : 1.000 : : 0.342 : sine $F\,D\,F^1$, whence sine $F\,D\,F^1 = 0.256$ = sine 14° 50¹, and 20° — 14° 50¹ = 5° 10¹ = difference of the angles of incidence and refraction. Now let $C\,D\,C^1 = 25°$, whose sine is 0.4226, then we have

1.336 : 1.000 : : 0.4226 : sine $F\,D\,F^1$, whence sine $F\,D\,F^1$ = 0.3163 = sine 18° 26¹, and 25° — 18° 26¹ = 6° 34¹ = difference of the angles of incidence and refraction.

It is clear therefore that for rays of light striking the same medium at different angles of obliquity, the *difference* between the angles of incidence and refraction is not the same, neither is the *ratio of the angle* of refraction to the *angle* of incidence the same, seeing that

$$20° - 14°\ 50^1 = 5°\ 10^1 \text{ and } 25° - 18°\ 26^1 = 6°\ 34^1$$
$$\text{and also } 1.336 : 1.000 : : 5°\ 10' : 6°\ 46'$$

and not 6° 34¹. The index of refraction designates therefore the ratio of the *sine of one angle* to the *sine of the other angle*, as shown by the lines $x\,y$ and $m\,n$ in the figure, which ratio alone is constant for the same medium.

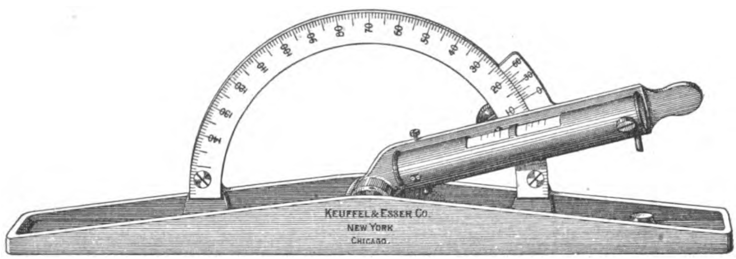
The converse of the above holds good, as when a ray of light passes through and from water into air. It is also well to remember that the refracted ray passing out of a rarer medium into a denser one (as from air into water or glass) is deviated *toward* the perpendicular to the surface of the refracting medium, that is, the angle of incidence $C\,D\,C^1$ is greater than the angle of refraction $F\,D\,F^1$; and the refracted ray passing out of a denser medium into a rarer one is deviated *from* the perpendicular, that is, the angle of incidence is less than the angle of refraction. These angles are always those bounded by the direction of the ray of light and the perpendicular to the surface of the refracting medium.

The operation of this law of light, as demonstrated, does not apply to water alone, but equally to glass and other media, with however the

difference that the index of refraction varies according to the medium. As glass, of one kind or another, is the substance which interests us mainly in those descriptions of optical and scientific instruments, we give, for the information of those of our readers who may like to pursue this branch of our subject further than our space permits of our doing, the refractive indices of various kinds of glass, thus: —

Crown Glass	from 1.525 to 1.534
Plate Glass	" 1.514 to 1.542
Bottle Glass	1.582
Flint Glass	from 1.590 to 1.625

A NEW CLINOMETER.



THE CLINOMETER or Slope Level shown in the above figure has been specially designed to meet the requirements of certain classes of work. It consists of a straight brass bar, 9 inches long, with side ledges, to the centre of one of which is pivoted an arm having attached to it a fine graduated bubble and a vernier. There is also attached to the bar an arc of 180 degrees, divided into single degrees and reading with the vernier to 5 minutes. The bubble arm can be clamped to the arc, when required, by means of a milled-headed screw at the back of the arm; a stop is also provided for bringing the vernier zero at once to zero of the arc, while three set screws are provided for adjusting the bubble tube and bringing the bubble into the centre of its run when the zeros of the arc and vernier coincide, by means of the principle of reversion, set forth in our articles on the adjustments of instruments. The extra length of the bar and its broad, flat underface, make the use of this instrument very advantageous when the surface on which it is placed is somewhat uneven.

These Clinometers are very carefully made, and the bubbles being adjustable, may be used for delicate work. The value of a single division of the bubble tube is about 2′ so that differences of level as fine as one minute may be easily estimated.

THE COMPASS.

A Monthly Journal published the first of every month, at 127 Fulton Street, New York City.

WILLIAM COX, - - - - - - - Editor.
KEUFFEL & ESSER CO., - - - - - Publishers.

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CORRESPONDENCE should be addressed to the Editor of THE COMPASS, 127 Fulton Street, New York City.

All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

WE ARE NOW in a position to announce in reply to numerous inquiries that the "DUPLEX" SLIDE RULE is on the market, and may be obtained of Keuffel & Esser Co., the publishers of "THE COMPASS," and the owners of the American, Canadian and all European patents. The price will be found on the back cover of this issue.

Those of our readers who are not acquainted with the special features and advantages of this improved Slide Rule, will find a short description of it, with a few practical examples of its great utility on page 146 of the present number.

ADJUSTMENTS OF SURVEYING INSTRUMENTS. VII.

THE TRANSIT.

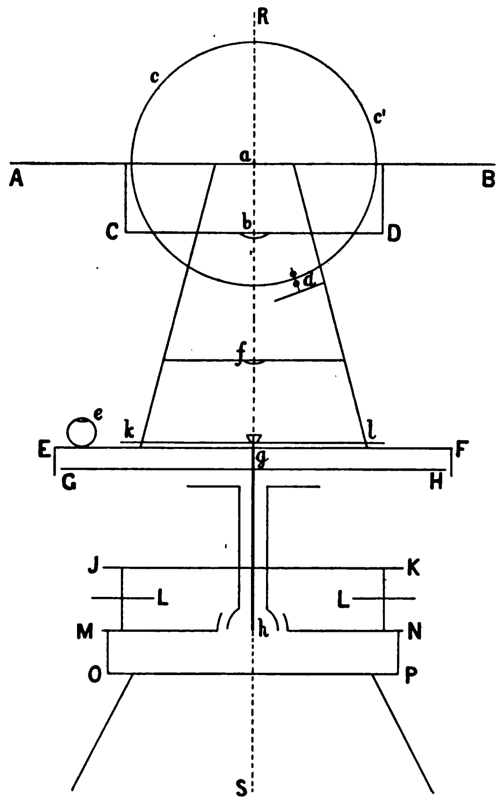


Fig. 1.

THE ADJUSTMENTS of the Transit which require the engineer's attention may be divided into two classes, those appertaining to the measurement of horizontal angles, and those relating to leveling and the measurement of vertical angles. These adjustments are

1. The Plate Levels,
2. The Line of Collimation,
3. The Standards.
4. The Telescope Level, and
5. The Vertical Circle.

We will examine these adjustments in order, and after showing what is signified by each one, explain how they are effected.

1. By the adjustment of the Plate Levels, their axes are made parallel to the top plate *E F*, so that *R S* may then be ascertained to be a true vertical and *E F* perfectly horizontal when the bubbles *e* and *f* are in the centre of their respective runs; the top plate *E F* and the horizontal limb *G H* are by construction made perpendicular to the centres *g h*.

2. The adjustment of the Line of Collimation consists of two operations; first, to ascertain that the cross hairs are truly vertical and horizontal, that is, that the horizontal cross hair is parallel to *E F*, and that the vertical cross hair is parallel to or coincides with *R S;* and second, to ascertain that the point of intersection of these cross hairs coincides with the line of collimation.

3. The adjustment of the Standards ensures the horizontal axis of revolution of the telescope being parallel to the top plate *E F* and perpendicular to *R S*.

4. The adjustment of the Telescope Level, by which the line of collimation *A B* is made parallel to the level axis *C D*, and consequently to the axes of the plate levels when the three bubbles are in the centre of their runs, is required when the transit is used for leveling purposes, and

5. The adjustment of the vertical circle, by which the vernier zero and the zero of the vertical limb are made to coincide when the line of collimation *A B* is horizontal, or parallel to *E F*, as shown by the telescope bubble, is necessary for the correct reading of angles of elevation or depression.

The object of these adjustments, it will be seen, is therefore to ascertain that the planes of revolution of the several parts of the instrument are parallel or perpendicular to one another, and are all perpendicular (each one in its own direction) to the true vertical *R S*, however these different parts may be revolved upon their axes.

In considering the manner of effecting these adjustments we shall have occasion to mention two distinctly different circular motions of the telescope,—the one a vertical motion in altitude upon its horizontal axis, and the other a horizontal motion in azimuth upon its vertical axis. In speaking of these we shall, in order to avoid confusion, refer in the former case to the telescope being *revolved*, and in the latter case to its being *turned round.*

We now come to the methods of effecting these adjustments, and

1. The Plate Levels, *by which R S is ascertained to be vertical, and E F to revolve in a horizontal plane.*

Set up the Transit on its tripod with the top plate (judged by the eye) as level as possible, then unclamping the plates, turn the instrument round so as to bring each one of the plate levels parallel to one of the pairs of opposite leveling screws.

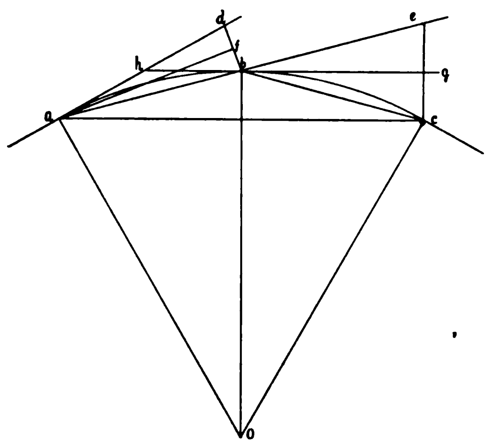
Now proceed to bring one after the other each of the bubbles into the centre of its run by means of the leveling screws, remembering that when it is required to raise the right hand side of a tube, as shown to be necessary by the bubble being to the left of the centre of its run, the opposing screws parallel to it should be turned by directlng both thumbs inwards, and the reverse when the left hand side should be raised. In Fig. 1 the screws *L L* must be operated on to influence the bubble *f*, and the other pair of screws to affect the bubble *e*. Care must be taken not to disturb the instrument while the two bubbles are being centred. It will probably be seen that the adjusting of the second bubble has affected the first one, and that it again needs attention. When eventually both bubbles are accurately centred, turn the top plates half way round so as to reverse the position of the level tubes in regard to the leveling screws, and note if the bubbles come to their centres as before. If they do, proceed to examine if they will remain centred during a whole revolution of the plates on their spindle. Should, however, the bubbles not run to their centres, then the axes of their tubes are not parallel to the top plate, and *half* the error must be corrected by means of the capstan headed nuts at the end of the level tubes as described on page 114, and for doing which an adjusting pin is always provided. When this is done, centre the bubbles again by means of the leveling screws *L L*, and verify in all positions of the top plate, repeating the correction as often as may be necessary until the bubbles remain accurately centred througout a complete revolution of the top plate on its spindles. The axes of the level tubes are now parallel to the top plate, the plane *E F* is a horizontal one, and the centres *g h* of the Transit coincide with the true vertical *R S*.

The reason why only half the bubble error must be corrected by means of the capstan headed nuts at the end of the level tubes will be clear if our preliminary observations (page 58) have been followed, in which we showed that the principle of reversion not only made an error of adjustment apparent, but determined its quantity, this visible quantity being double the error. By correcting, therefore, half the apparent error, we, in fact, rectify the whole of the real error. The subsequent operation of bringing the bubbles into the centres of their runs by means of the leveling screws must not, therefore, be considered as a correcting of the bubble error, but merely as a leveling again of the plates, assuming that the axes of the small level tubes have now been made parallel to the top plate.

DEFLECTION ANGLE OR TANGENTIAL ANGLE?

A SHORT TIME ago the following letter appeared in *The Railroad Gazette*, addressed to its editor :—

"I solicit your aid in the direction of securing greater uniformity in the nomenclature of the angles employed in locating railroad curves. My references are to the figure inclosed.



The Field Books of Henck and Searles apply the name "deflection angle" to the angle *d a b* formed between a 100-ft. chord *a b*, and a tangent *a d* at one end of that chord, which is the constant angle *d* a *b* = *b a c* turned off (or "deflected") by the transitman from one point *a* in locating points *b*, *c*, etc., in the curve at the ends of 100-ft. chords.

But Shunk's and Trautwine's books call this the "*tangential*" angle (owing, no doubt, to the fact that the tangent *a d* forms one of the legs ot the angle) and apply the term "deflection angle" to the *double* of this, *i. e.*, to the angle *e b c* formed between one 100-ft. chord *b c* and the prolongation *b e* of the preceding 100-ft. chord *a b*; which, of course, is equal to the angle *d h b* between two tangents *a d* and *h g*, touching the curve at the two ends *a* and *b* of a 100-ft. chord, or to the central angle *a o b* = *b o c* subtended by one 100-ft. chord. It is the angle through which the curve *deflects* within the length subtended by one 100-ft. chord, and is generally called the "degree of curvature."

It seems most unfortunate that so confusing a difference of nomenclature should be perpetuated, and I would ask for expressions of opinion from yourself and from your readers as to the relative merits of the two systems and the extent to which each prevails, in the hope that one pair

of authors (no matter which) may be induced to bow to the inevitable and conform to general usage.

SIMPLEX."

The first reply to the above was as follows:—

"To the editor of the *Railroad Gazette*:—

I shall await with interest the replies that may be called forth by the inquiry of your correspondent, Simplex, respecting the nomenclature of the angles used in the loeation of curves.

Simplex is right in supposing that our tangential angle is so called from the fact that the tangent forms one side of it. Or, as stated in our book on curves, "The first of these angles is called the tangential angle, as being that by which the curve is connected with the tangent, but inasmuch as the others are all equal to it they also are called tangential angles."

My own impression is that the balance of usage is in favor of the use of the terms as employed by Henck and Searles, but of this we may be better able to judge when the returns are in.

JOHN C. TRAUTWINE, JR."

Later on, replies were received from the following, all of whom are in favor of calling the angle *d a b* the Deflection angle.

C. Frank Allen, Professor Railroad Engineering, Massachussetts Institute of Technology;
Ward Baldwin, Professor Civil Engineering, University of Cincinnati;
Channing M. Bolton, Chief Engineer Richmond & Danville Railroad;
C. L. Crandall, Professor Civil Engineering, Cornell University;
William E. Hoyt, Chief Engineer, Buffalo, Rochester & Pittsburgh;
Olin H. Landreth, Professor of Engineering, Vanderbilt University;
Emile Low, Engineer Department, Norfolk & Western;
G. B. Nicholson, Chief Engineer, "Queen & Crescent" System;
Joseph T. Richards, Engineer Maintenance of Way, Pennsylvania Railroad;
Wm. H. Searles;
Geo. H. White, Professor of Civil Engineering, Worcester Polytechnic Institute.

Mr. Walter Katte, Chief Engineer, New York Central & Hudson River Railroad alone makes out a very good case in favor of Trautwine's designation, and as we think a fair chance should always be given to a minority, we append his reasons, as given in his letter to the Editor of the *Railroad Gazette*. He says,—

"When I was a "field" practitioner some 25 or 30 years ago, the invariable practice (as far as my recollection now serves) was to call the angle *d a b* the "tangential" angle, and the angles *e b c*, *a o b*, *b o c*

"deflection" angles, *never* applying the term "deflection" to the "tangential" angle *d a b*. This seems to me to be the proper, common-sense nomenclature for these angles, for the reason that "deflection" naturally suggests what *it is*—*i. e.*, the "deflection" or "change of course" which the curve has obtained at the end of each successive 100 feet. This is not the case when applied to the "tangential" angle, as that of course is always exactly one-half the deflection angle, and applies only at the beginning and the end of a curve, and is simply the angle which the *first* and last chords make with the tangent."

THE METRIC SYSTEM.

In our February issue we gave our readers a copy of a circular which had been sent out by the New Decimal Association of London, England, in which it was stated that the Chancellor of the Exchequer and the President of the Board of Trades had been asked to hear the views of the leaders and advocates of the metric system, and that they had promised to receive a deputation on the 25th of January.

We learn from the English papers that the result was not as satisfactory as was hoped, as Sir William Harcourt confined his remarks almost entirely to the question of coinage, passing over with a casual observation the more important issues of weights and measures.

We are glad to know however that the New Decimal Association intend to agitate and "press for a change of the weights and measures first, and to deal with the more thorny question of a decimal coinage afterwards. As a first step, it is proposed to ask for a Select Committee to consider the question in the light of present requirements, and then the case can be fully stated and investigated.

That the subject is one of international interest is undoubted. In Europe the use of the Metric System is obligatory in 12 countries with a population of over 200 millions. In Central and South America it is obligatory in 10 States with a population of 40 millions, while in 10 small States having a population of 10 millions, it is legalized and is more or less in use. This, to manufacturing countries like the United States and England, should be a weighty consideration, seeing that the absence of uniformity and conformity to the usages of importing countries often leads to serious diversions of trade. Instances of such results are frequently given in our own and in English Journals, and if collated would present such an array of facts as would cause many an American Machinist or Manufacturer to ponder whether important advantages would not accrue to this country by a little more observance of and agreement with the

systems of weights and measures in vogue in those numerous countries with which we have such great and important commercial dealings.

To the Civil Engineer practicing in South and Central America, acquaintance with the metrical system of weights and measures is an absolute necessity; to the Hydraulic and Mining Engineer the relation between length, volume and weight is immensely simplified, seeing that

1 Cubic Metre of Water = 1000 Litres = 1000 Kilogrammes,

there being thus agreement between the three measures; to the Machinist or Manufacturer compliance with foreign usages and preferences would increase materially the importance of his export trade; while to one and all the simplicity of the system, when fully understood, would be a great relief.

To the honor of this country, be it said, "in the Coast and Geodetic Survey the metre has been in use exclusively as the unit of measurement, and in the Lake Survey in the measurement of its later base lines. The application of the metric system appears also in the acts relating to coinage, in which the weight of the half dollar, the quarter, and the dime are expressed in grams." *

Let us hope that our pioneers of industry will make themselves fully acquainted with the metric system and the advantages which it offers; its adoption in commerce and science will then surely follow.

We shall be glad to receive and give expressions to the views of any of our readers on this important question.

K. & E. POCKET FOLDING RULES.

IT MAY INTEREST some of our readers to know that since we described these convenient Pocket Rules, (Jan. 1893) some additional forms of them have been placed on the market.

The 4-foot rule with spring joints, shown in figure 1, may now be had divided on one side in inches and sixteenths, and on the other side in inches with subdivisions of tenths and half-tenths. This decimal division will be found in many cases a great convenience.

The ordinary pocket rules, 2 and 3 feet long, similar to figure 1, but without the spring joints, may also now be had about 5 inches long when folded up (instead of with 7 inch links) giving 4 inches between the centres of the joints, thus making the 2 foot in 6 folds and the 3 foot in 9 folds. This size will be found more convenient for the pocket.

In case of breakage these rules may be sent to be repaired, or spare links may be obtained, if preferred.

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* Report of Professor T. C. Mendenhall, Superintendent U. S. Coast and Geodetic Survey and of Weights and Measures. September 16, 1889.

BOOKS RECEIVED.

TIPS TO INVENTORS.—Telling what inventions are needed, and how to perfect and develope new ideas in any lines. By Robert Grimshaw, Ph. D., M. E., The Practical Publishing Co., New York, 1893. Price $1.00

This little work is intended to be both a guide and an incentive to those who are of an inventive turn of mind. It briefly recounts some one hundred and fifty odd subjects, problems or processes, whose solution at the present time is either non-existent or leaves much to be effected in the way of improvement and perfecting. The most valuable part of the book is perhaps the advice to those who have started an idea, as to the best steps to take in working it out, and the errors to avoid, so that a happy consummation of the inventor's hopes and ambitions may be attained.

Tables of the area and the population of the countries and chief cities of the world are added, probably to guide the inventor as to the relative value of the different foreign patentsmight be induced to take out.

WE HAVE RECEIVED from Robert Poole & Sons Co., of Baltimore, their new (1893) List of Gearing, Pulleys, &c. The reputation obtained by this firm for their machine-molded gears will make this book containing particulars of over 5000 forms of great use to the engineer. This firm is also full equipped for suppling cut and plained gears of all kinds, from the smallest to a gear 50 ft. diameter. Several tables are appended which add to the value of the book.

CHARLES H. HASWELL.

IT IS ALWAYS pleasing to note such testimony as the following. The editor of the *Engineer* says there is no more striking figure in any profession to-day than that of Charles H. Haswell, who at the age of 84—is still actively at work daily. Notwithstanding his years he is as erect as an athlete, and apparently as tireless, he goes about, up and down long flights of stairs to offices where there are no elevators, transacts even trivial matters, and has, apparently discovered the fountain Ponce de Leon sought for unavailingly. We think it would be hard to find anywhere in the world another professional man who is doing the work that Mr. Haswell does constantly, both physical and mental. We should be proud of the career of this veteran American engineer and honor him while he is still in the flesh.

A Monthly Journal for Engineers, Surveyors, Architects, Draughtsmen and Students.

Vol. II. JUNE 1, 1893. No. 11.

THE HELIOGRAPH.

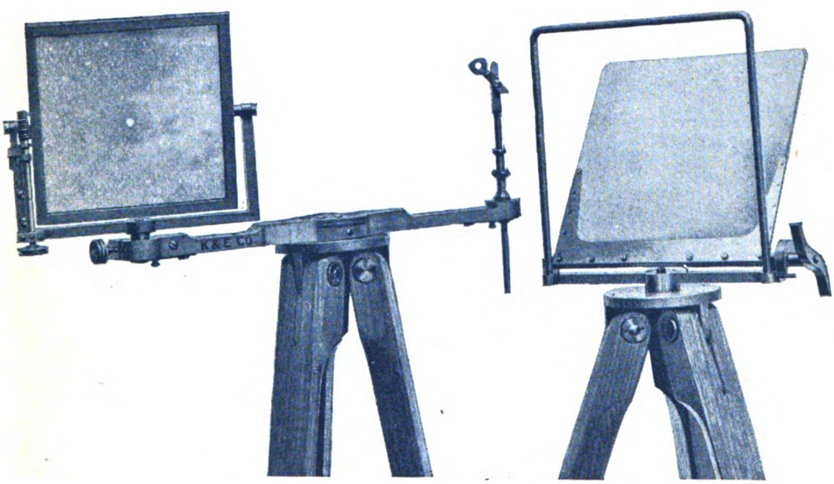


Fig. 1.

THE ABOVE FIGURE represents the heliographic outfit used for the interesting experiments recently made between New York and Brooklyn, and to which we briefly referred in our last issue. It consists of the following parts, the references being to Fig. 2.

A. A.[1] Two Tripods;

B. A Sun Mirror, which revolves in a conical socket at one end of

C. The Mirror Bar;

D. A Sighting Rod, with movable disk, which fits in a similar socket at the other end of the mirror bar;

E. A Screen, screwed on to the head of tripod *A*[1], by means of which intermittent flashes of light, reflected from the sun mirror, are produced.

Another mirror, called the Station Mirror, (not shown in the figure) completes the outfit. This mirror is similar to the sun mirror in all respects but one; this difference and the object of the second mirror will be referred to further on.

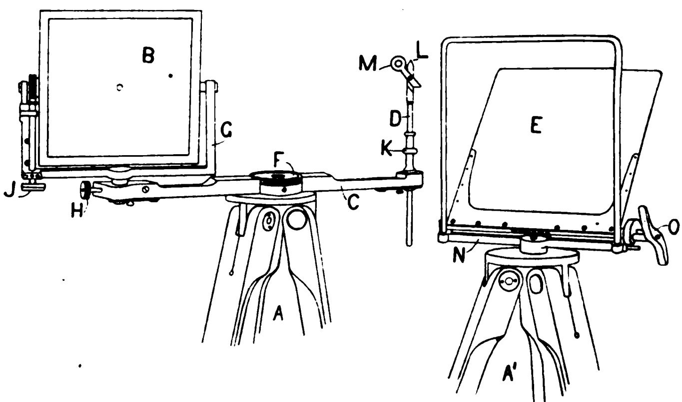


Fig. 2.

The Tripods when set up are about 40 inches high. In the centre of each tripod head is a screw, (both screws being of the same diameter and pitch of thread) one for receiving the mirror bar *C*, and the other for the screen *E*. The mirror bar, which is 12 inches long, can be fixed in any desired position by means of the circular clamping screw *F*. Under the tripod head is a substantial hook, from which a heavy weight can be suspended to render the instrument more stable in windy weather.

The Sun Mirror consists of a frame *G* having a conical stud or spindle on its under side which fits accurately into the socket at the end of the mirror bar, and is there secured by means of a spring clamp on the underside of the bar, which, however, does not prevent the frame from being revolved on its axis as desired. The sun mirror proper *B*, is capa-

ble of rotary motion about a horizontal axis, revolving in suitable bearings in the frame *G*. In the centre of this mirror is a small unsilvered spot, through which the operator, when standing behind it, can see the sighting point *L* and the receiving station. A tangent screw *H* is provided for turning the sun mirror round upon its vertical axis with a slow and steady motion, while another tangent screw *J* enables the mirror to be turned round very gently upon its horizontal axis, thus allowing of its being set very accurately in position to receive and transmit the light as desired.

The Sighting Rod D fits in the other socket of the mirror bar, is there secured by a spring clamp, and can be adjusted to any height, its desired position being maintained by means of a sliding nut *K*. It consists of the sighting point *L*, and a small movable disc *M* which can be turned up or down so as to cover or uncover the sighting point *L*.

The Screen E consists of a thin plate of vulcanized fibre, hinged to the frame *N* which is screwed on to the tripod head. A handle or key *O* permits of the screen being turned down so that the rays of light reflected from the sun mirror may be seen at a distance, while a spiral spring at once restores it to its normal position when pressure is taken off the handle.

Such are the parts composing the Heliograph with the exception of the *Station Mirror*, which as stated, is like the sun mirror, except that in place of an unsilvered spot in the centre, it has a corresponding white opaque spot. This mirror is only used when the sun is behind the operator, and then serves to reflect to the receiving station the sun's rays which it receives by reflection from the sun mirror.

The method of operating with the Heliograph is briefly as follows:—The instruments are set up as shown in the figure, a sight being taken from behind the sun mirror, through the unsilvered spot, to the receiving station, the top point of the sighting rod being then placed in this line. The mirror is next adjusted by means of the tangent screws so that the "shadow spot" shall fall upon the sighting rod disk, in which a piece of white paper has been previously inserted; a ray of light reflected from the the mirror will now strike the receiving station. This done, place the screen so as to intercept the ray, then by means of the screen handle make intermittent flashes of light as desired.

When the sun is behind the operator the sighting rod is replaced by the sun mirror and the two mirrors adjusted to produce a double reflection of the sun's rays, when intermittent flashes may be produced as required. Care must be taken when signalling, to keep the sun mirror all the time so adjusted by means of the tangent screws that the shadow spot shall remain in the centre of the disk, otherwise the flashes will cease to be transmitted to the receiving station.

The signal code and the conventional signals used are those of the *American Morse Alphabet*, issued in leaflet form by General A. W. Greely,

Chief Signal Officer U. S. A., dated July 1, 1889, and authorized by G. O. 59, A. G. O., June 28, 1889.

The sun's light is reflected from the surface of the mirror in a cone of rays, the apex angle of which is equal to that of the sun's diameter, or about 32 minutes, so that the lateral space covered by the flash may be taken at $\sin 32' \times 5280 = 49$ feet per mile. Although the area thus covered by the cone of rays may appear considerable, yet it is advisable that the adjustment and alignment of the instruments be as perfeet as possible, as the maximum intensity of light is then transmitted to the receiving station. These reflected rays are discernible by the naked eye at from 30 to 50 miles, and under very favorable conditions have been seen by means of telescopes at nearly 100 miles.

A complete Heliographic outfit comprises 2 tripods, 1 mirror bar, 1 sun mirror, 1 station mirror and 1 screen for *each station.*

In Geodetic surveying when the distance or the state of the atmosphere is such that a target can be but barely discerned, a heliotrope (that is, a heliograph without the screen) is sometimes made use of to indicate the position of a station, thus materially assisting in determining angles, etc. The instruments we have described answer admirably such a purpose, the mode of using them being as described.

Besides the use of these instruments in our own country, as referred to in our last issue, they have been adopted by the Military Schools and Colleges of Mexico, Columbia and Guatamala.

Our previous remarks have had special reference to the transmission of the sun's rays to distant points, but as this is not at all times possible, the Heliograph may be used in conjunction with any suitable artificial light, thus adding materially to the occasions when it may be profitably employed, either by day or by night.

LIGHT: ITS REFLECTION AND REFRACTION. VIII.

A PRISM IN OPTICS is used to designate a solid composed of any transparent substance or medium, having two plane surfaces *A B C D* and *E F C D*, inclined to and intersecting one another in *C D*, these bounding surfaces or planes being called the *faces* or refracting surfaces of the prism, while the line *C D* formed by the intersection of the faces is called the *edge* of the prism. The third side *A B E F*, enclosing the solid, is called the *base* of the prism, and the angle formed by the intersection of the faces is called the *refracting angle* of the prism.

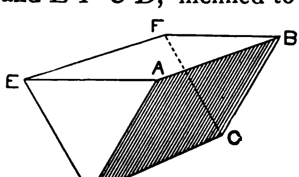


Fig. 1.

The laws which govern the transmission of light through different media have been placed under contribution in various ways to obtain instruments by means of which angles or directions, as well as distances, may be determined, and as the glass prism is that form and kind of solid medium which has been found most suitable for such purposes, and has therefore, been mostly adopted in the construction of such instruments, we shall briefly explain the modifications produced upon rays of light as they pass through the refracting surfaces of glass prisms.

We showed in our last, that when a ray of light emerges from a medium of one density and enters obliquely a medium of a different density, the direction of its course is altered, and that this change of direction varies with different media, but that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is always the same for the same medium, whatever may be, within a certain limit, the obliquity of the incident and emergent or refracted rays.

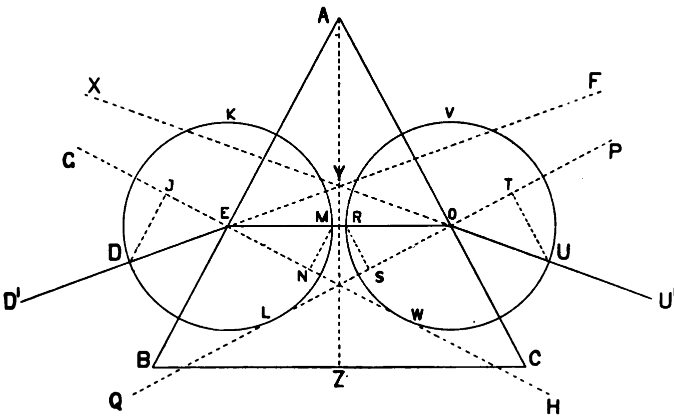


Fig. 2.

Let in Fig. 2 *A B C* be the section of a flint glass prism, and let *D*' *E* be a ray of light falling upon the face *A B* of the prism, and which, if unobstructed in its course by the interposition of a medium of different density, would proceed to *F*. Let also *G H* be a perpendicular to the face *A B*, termed in optics the *normal*, then taking the index of refraction of flint glass as 1.6, the sine of the angle of incidence *G E D* would be to the sine of the angle of refraction within the prism, as 1.6 to 1.0. Now by any convenient scale, lay off *D J* equal to 1.6 or 16 parts, parallel to *A B*, and with *E* as centre and *D E* as radius, describe the circle *D K L*, then lay off *M N*, equal to 1.0 or 10 parts by the same scale, and also parallel to the face *A B*; join *E M* and produce it to *O* on the face *A C*. It will be clear now that *G E D* is the angle of incidence of the ray of

light, and *O E H* the angle of refraction, the ratio of the sine *D J* of the former being to the sine *M N* of the latter as 1.6 is to 1.0, so that *E M O* is evidently the direction of the ray of light *D E* as it penetrates the medium or prism *A B C.* Now draw *P Q* perpendicular to the face *A C*, then as before lay down *R S* equal to 1.0 or 10 parts, describe the circle *V U W*, lay down *T U* equal to 1.6 or 16 parts, and join *O U* producing it to U^1; then is *O* U^1 clearly the direction of the ray emerging from the prism, *R O S* being the angle of incidence and *T O* U^1 the angle of refraction as regards the face *A C*, the sine *R S* of the former being to *T U*, the sine of the latter, as 1.0 is to 1 6. We have, therefore D^1 *E O* U^1 as the course followed by the ray of light through the prism, and to an observer, situated at U^1, an object at *D* would appear as if placed at *X*, in the prolongation of the emergent ray *O* U^1, the angle of deviation of the ray being $F\ Y\ U^1 = D^1\ Y X$.

We have said that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is the same for the same medium, whatever may be, *within a certain limit*, the obliquity of the incident and emergent or refracted rays. This limitation is called the *Limit of Refraction* or the *Limit of Possible Transmission*, and is a natural consequence of the law of refraction, its effect being at once apparent in the case of a ray of light emerging from a denser medium into one of less density. Let us suppose for instance, a piece of glass, with two parallel plane faces, whose index of refraction is 1.6, and a ray of light passing through it and into the air, the ratio of the sine of the angle of the incident ray to the sine of the angle of the refracted ray would be as 1.0 is to 1.6. Now if the angle of incidence be 30°, its sine is 0.5, so that the sine of the angle of the refracted ray would be $0.5 \times 1.6 = 0.8$, thus making the angle of refraction 53° 8′. If we now suppose the angle of incidence to be 45°, whose sine is 0.707, then the sine of the angle of refraction would be $0.707 \times 1.6 = 1.131$, which represents an angle greater than 90 degrees. As the surface of the medium forms with the normal, or perpendicular to its surface, a right angle, it is clear that the ray of light cannot emerge from the denser medium, but the refraction would have, if such were possible, to transmit the ray back again into the medium. There is, therefore a certain angle of incidence at which refraction ceases. This angle, called the *critical angle*, may be very easily ascertained thus,

$$\text{Sine } 90° \div \text{Index of Refraction} = \text{Critical Angle},$$

so that in the case before us we have $\frac{1}{1.6} = 0.625 = \text{sine } 38° 41'$ as the limiting angle beyond which refraction is impossible. It is self-evident that a ray of light in a transparent medium cannot be totally extinguished,

so when refraction becomes impossible, then reflection must take place, and it follows in such cases the laws already laid down under that head.

It will be at once seen from what precedes that the critical angle of one medium is different from that of another, and that it is in inverse proportion to the index of refraction; thus we have

Medium	Index of Refraction.	Sine of Critical Angle.	Limiting Angle of Incident Ray.
Crown Glass	1.525 to 1.534	0.655 to 0.652	40° 56′ to 40° 42′
Plate Glass	1.514 " 1.542	0.660 " 0.649	41° 20′ " 40° 26′
Bottle Glass	1.582	0.632	39° 12′
Flint Glass	1.590 " 1.625	0.629 " 0.615	38° 58′ " 37° 59′

This principle of a limiting or critical angle beyond which reflection takes place, is frequently made use of in scientific instruments in preference to mirrors, thus in Fig. 3, let *A B C* be the section of a glass prism, right angled at *A*, and let *E E*¹ be a ray of light proceeding from *E* and striking the face *A B* of the prism perpendicularly at *E*¹. As shown in our last, such a ray, would continue in its course in the same straight line and proceed towards *D*. At *D* the ray *E*¹ *D* is an incident ray as regards the base *B C* of the prism, and the angle of incidence *A D E*¹ being an angle of 45°, is greater than the limiting angle of refraction of glass, (which varies between about 38° and 41°) therefore the ray cannot emerge or be refracted, but is internally reflected. As therefore, according to the laws of reflection the angle of reflection is equal to the angle of incidence, this latter must also have 45°, and the ray will consequently follow the direction *D F*¹, striking the face *A C* of the prism perpendicularly, and continue its course in the same straight line towards *F*. An observer at *F* looking straight into the face *A C* of the prism would therefore see an object at *E* as if it were at *G*, the apparent direction of the ray being *G D F*, and the deviation of its final direction from its initial direction being 90 degrees.

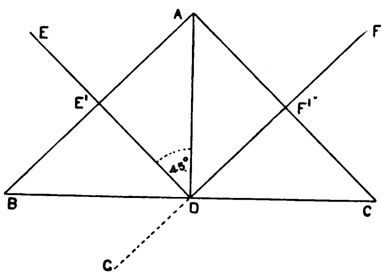


Fig. 3.

Fig. 4 represents a small mounted Rectangular Prism, with handle, which is often used for setting out perpendiculars, exactly in the same manner as the Angle Mirrors already described. The handle is provided with a small hook to which a plumb line can be attached to determine the apex of the right angle.


Fig. 4.

THE COMPASS.

A Monthly Journal published the first of every month, at 127 Fulton Street, New York City.

WILLIAM COX, - - - - - - - Editor.
KEUFFEL & ESSER CO., - - - - - - Publishers.

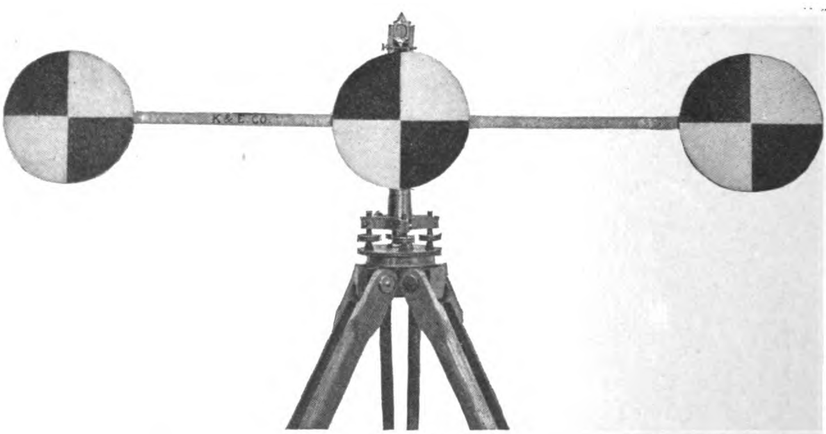
***SUBSCRIPTION* $1.00 per year, in advance, postage paid. Single Copies, 10 Cents each.**

***CORRESPONDENCE* should be addressed to the Editor of THE COMPASS, 127 Fulton Street, New York City.**

All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

A NEW TELEMETER TARGET.



THE ABOVE figure represents a new target, invented and patented by Mr. Claudio Urrutia, of Guatamala, and manufactured and sold by Keuffel & Esser Co. With this apparatus and an Engineer's transit, whose

horizontal and vertical limbs read at least to single minutes, the distance of remote objects may be easily and quickly obtained, and that with a degree of precision depending solely upon the care bestowed upon the manipulation and accuracy of the instruments used.

To the engineer, working in mountainous districts, this invention will prove of great value, enabling him, as it does, to obtain both horizontal, vertical and inclined distances without having to encounter the tedium and the difficulties of chaining, and that with a greater degree of accuracy than with the gradienter or with the stadia.

The apparatus consists of 3 discs or targets firmly attached to a horizontal bar, the distance between their respective vertical diameters being exactly 50 centimetres (half a metre = 1.6404 feet.) The centre disc is connected with a vertical spindle capable of being revolved in a socket, which is provided with leveling arms, screws and a tripod plate, this latter being screwed on a tripod head, as is done in the case of a level, and as shown in the figure. Two bubble tubes are provided by means of which the spindle can be made perfectly vertical, and the disc bar consequently horizontal, in any position in which it may be placed, while a sighting arrangement, seen over the centre disc, enables the targets to be so adjusted that an imaginary line proceeding from the vertical diameter of the centre disc to the observer's transit shall be perpendicular to the bar, thus making with it two right angles. The exact spot whose distance is desired, is determined by a plumb bob suspended in the usual way. For convenience in packing the two arms of the bar are jointed, allowing of the three discs to be folded over each other.

The method of using this instrument is as follow:—It is mounted in position by means of the plumb bob at the end of the line which is to be measured, carefully leveled and sighted to the other end of the line where the transit is placed, then clamped by means of a screw behind the centre target. The observer at the transit then measures the horizontal angle subtended by the vertical diameters of the two outer targets, repeating the measurement until a total angle of at least 3 degrees has been obtained. The total angle and the number of measurements being noted, we now calculate the *direct distance* by means of the following formula

$$\text{Distance in metres} = 0.5 \times \text{Cot}\,\frac{m}{2\,n} \,\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where m = total angle of all the measurements in minutes;
n = number of measurements taken;

or $$\text{Distance in feet} = 1.6404 \times \text{Cot}\,\frac{m}{2\,n} \,\ldots\ldots\ldots\ldots\ldots (2)$$

As, however, half the *mean* subtended angle is not likely to exceed 50 minutes, seeing that this would give a direct distance of 1.6404 × 68.75008 = 112.778 feet, we may simplify the above formula and assume that the

cotangent of an angle is inversely proportionate to the number of minutes in the angle, whence we obtain

$$\text{Distance in feet} = 1.6404 \times \text{Cot 1 min} \times \frac{2\,n}{m}$$

that is

$$= 1.6404 \times 3437.74 \times \frac{2\,n}{m}$$

$$\text{Distance in feet} = 11278.56 \times \frac{n}{m} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

the difference between this method and and the use of correct cotangents being but one-tenth inch for a distance of 112 feet, which difference diminishes as the distance becomes greater, becoming practically nil at 500 feet.

If the direct distance to the target is not a horizontal, but an inclined one, then it must be reduced to such by multiplying the inclined distance by the cosine of the angle of elevation or depression of the target, as found on the vertical limb of the transit, so that we have

$$\left.\begin{matrix}\text{Horizontal Distance}\\ \text{in feet}\end{matrix}\right\} = 11278.56 \times \frac{n}{m} \times \text{Cos } a \ldots\ldots(4)$$

where a = angle of elevation or depression of the transit telescope.

Should it be required to ascertain the vertical height from the horizontal plane passing through the transit telescope axis, we have

$$\left.\begin{matrix}\text{Vertical Height}\\ \text{in feet}\end{matrix}\right\} = 11278.56 \times \frac{n}{m} \times \text{Sin } a \ldots\ldots(5)$$

If the distances and the vertical height are required in metres, then we use the constant 3437.74 in place of the constant 11278.56, which gives us

$$\left.\begin{matrix}\text{Direct Distance}\\ \text{in Metres}\end{matrix}\right\} = 3437.74 \times \frac{n}{m} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The centre disc may be used in cases where obstacles prevent the sighting to be made on the two outer discs, care being then taken to divide the constants in the above formulæ by two.

This Telemeter Target has been submitted to many tests, and has been found to give very accurate results.

THE SECTOR. IV.

As MAY HAVE been gathered, a variety of problems can be solved by means of the Sector. With it, a pair of dividers and a finely divided or a diagonal scale, the surveyor or engineer, who does not wish to be burdened in the field or on a journey with a number of instruments, may make his

sketches, protract his angles and make his geometrical or trigonometrical computations with ease and a fair degree of accuracy. For purposes of calculation, however, the Sector must undoubtedly give place to the Slide Rule. We shall now close the subject with a few practical applications.

To make a vernier. On a given straight line lay off say an inch and divide it into 10 equal parts, as described page 123, then take in the dividers 9 of such parts and open out the Sector legs until this distance becomes a transverse distance from 10 to 10 on the lines of lines. The transverse distances 1 to 1, 2 to 2, etc., from one lateral scale to the other will then be divisions of the vernier, the lowest count being $^1/_{100}$th of an inch.

To use the Sector as a scale of inches and chains, or inches and feet, etc. Let it be required, for instance, to take off measurements from a drawing make to a scale of 1 inch = 3 chains. Take in between the points of the dividers one inch, and open out the Sector legs until it becomes a transverse distance between 3 and 3 on the lines of lines. The Sector is now "set" to serve as a scale of 3 chains to the inch, and all transverse distances, read on the lateral scales of lines, from a main division on one leg to the corresponding main division on the other leg represent chains, while the transverse distances from and to subdivisions represent chains and links.

In the same way scales of inches and feet, inches and miles, inches and metres, etc., may be set, and corresponding scales laid down on the drawing if desired.

Required the height of A B, Fig. 1, its base being inaccessible. Let $CD = 60$ feet, $ACB = 60°$ and $ADB = 35°$, then we have $CAD = ACB - ADB = 60° - 35° = 25°$.

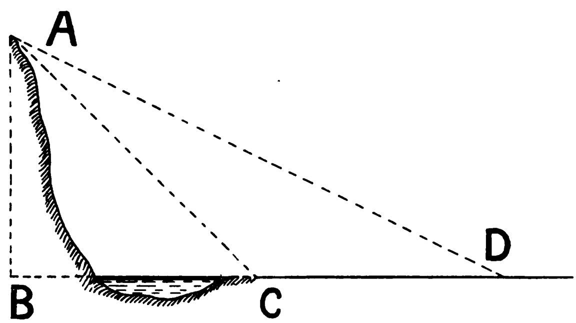


Fig. 1.

Now we have, according to the rules of Trigonometry,

(1). Sine $CAD : CD :: $ Sine $ADC : AC$ and

(2). Sine $ABC : AC :: $ Sine $ACB : AB$.

With the Sector the operations are

First. Take in the dividers from the line of lines or any other convenient scale 60 parts = *C D*, and open out the legs of the Sector so as to make them a transverse distance between 25 on one line of sines to 25 on the other line of sines = Angle *C A D*; then without disturbing the Sector, take in the dividers the transverse distance 35 to 35 of the lines of sines = angle *A D C*, and apply this to the same scale of equal parts, when $81\frac{1}{2}$ will be read off = *A C*, now

Second, with the dividers as just set = *A C*, make their opening coincide with the points 90 and 90 of the lines of sines = angle *A B C*, by opening out the legs of the Sector the necessary quantity; now take in the dividers the transverse distance 60 to 60 of the lines of sines =*A C B*, and apply it to the scale of equal parts, when $70\frac{1}{2}$ will be read off, which is the height of *A B*,

To determine the distance A B, the point A being inaccessible.

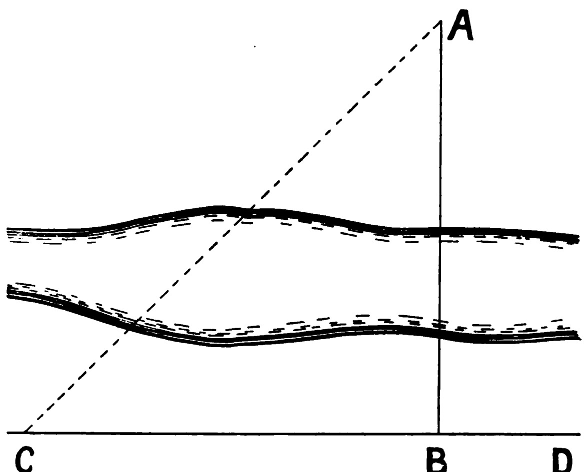


Fig. 2.

Measure off from *B*, at right angles to *A B*, a distance of say 100 feet = *B C*, then having measured the angle *A C B* = say 40°, we have *C A B* = 50°, whence

Sine *C A B* : *C B* : : Sine *A C B* : *A B*.

Take in the dividers as before, from a convenient scale, 100 parts and make them a transverse distance between 50 and 50 of the lines of sines. Now without disturbing the Sector, take in the dividers the transverse distance between 40 and 40 of the lines of sines, when upon applying this to the same scale of equal parts, we shall read off 84 feet as the distance *A B*.

The reason of these methods of working, with their results, will be clear when we remember that a given lateral distance is to its corresponding transverse distance, as any other lateral distance is to its corresponding transverse distance; and also that in any triangle the sine of the angle opposite a given side : the given side : : the sine of the angle opposite a second side : the second side : : the sine of the angle opposite the third side : the third side; so that all the sides of the triangle become transverse distances and the sines of the angles become lateral distances. It is immaterial whether we take the transverse distance from the lines of lines, or from any other and more convenient scale: the result will always be the same.

Before closing it is necessary that we say a few words about the lines of logarithmic numbers, sines and tangents (scales 10, 11 and 12, page 112). If the Sector be opened out to its full extent, it will be seen that these scales correspond identically with those of the slide rule: they may be used in the same way by taking off the distances with the dividers or on a slip of paper. The chief points to be borne in mind are that multiplication is effected by *adding* the distance represented by one factor to the distance represented by the other factor, when the total resulting distance represents the product, and that in division the distance corresponding to the divisor is *subtracted* from the distance corresponding to the dividend, the quotient being represented by the remaining distance. Multiplication is, therefore, always performed forwards to the right, and division backwards to the left.

A NEW PANTOGRAPH.

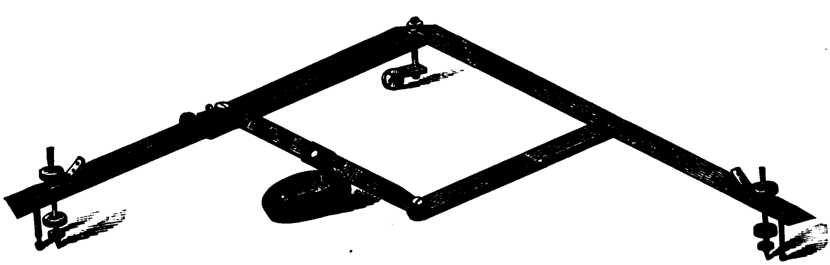


Fig. 1.

We described in a former number of The Compass (October, 1892) the principles which govern the construction and use of that form of Pantograph by which the reproduction of a design is obtained in a reversed position, and which is generally adopted for the better class of instruments. We also stated that the bars *A F* and *A T*, Fig. 2, are in these

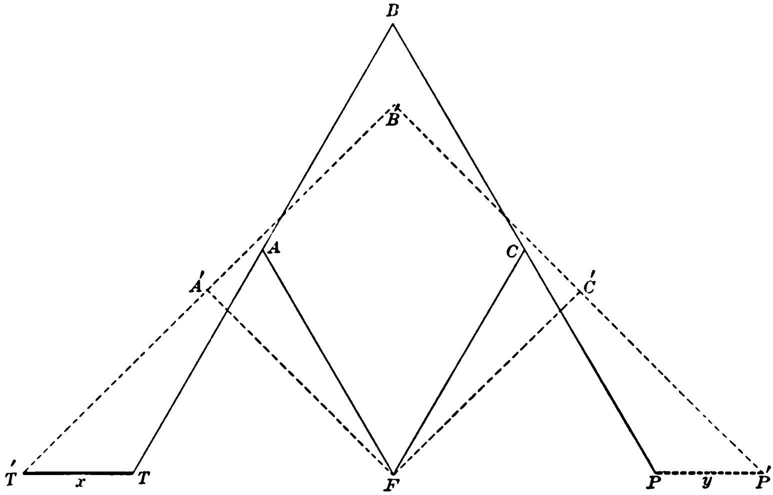


Fig. 2.

instruments fully graduated, so that by means of a simple formula the left bar and the fulcrum sockets can be set to any desired proportion.

The price of these high-class and well-finished instruments, (described in Vol. I, p. 77) has, however, often proved an obstacle to their more general adoption. To meet, therefore, a long felt want, our publishers have recently brought out a modified and improved form of one of their older instruments, which practically is capable of being used within the limits of, and for the same work as the higher priced Pantographs.

This instrument, shown in Fig. 1, is made of triangular brass tubes, carefully jointed together. A fixed socket is attached to the ends of the bars *A T* and *C P*, in either one of which a pencil point or a tracer point can be secured. The bar *B P* is in one piece, but the bar *A T* telescopes, that is, when it is required to be shortened so as to reproduce a drawing in any ratio other than that of 1 to 1, as shown in Fig. 3, the length *A T* is made to slide within the bar *A B*, being held in the required position by a set screw at *A*. This bar *A T* is fully graduated, the distance from *A* to *T*, when the instrument is set to 1 to 1, as in Fig. 1, being divided into 60 equal parts, which are numbered on the left-hand side consecutively 5, 10, 15, etc. Various fixed proportions from 1 to 1, 9 to 10, 5 to 6, etc., down to 1 to 6 are marked on the right-hand side of their corresponding divisions.

The fulcrum socket slides on the bar *A F*, and on the under side of the fulcrum has a small hole into which a short pin fits, which is used for setting the fulcrum.

To set the Pantograph to any proportion, say 4 *to* 5.

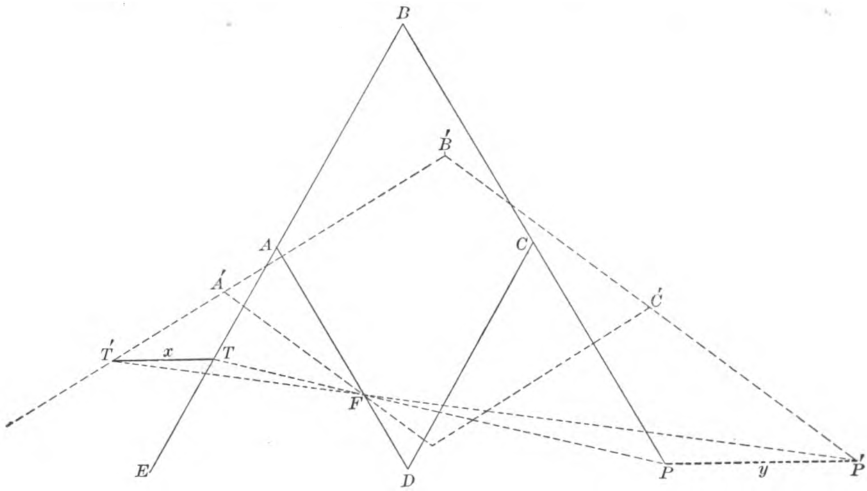


Fig. 3.

Slide the bar $A\ T$ in the bar $A\ B$ until the 17th division, upon which is indicated the ratio 4—5, just touches the lower end-edge of the bar $A\ B$, and clamp it firmly. Now on the edge of a piece of paper draw a straight line, and set the points T and P upon this line, the opening out of the arms of the pantograph being about as shown in the figure. Having put the small pin into the hole in the fulcrum, slide the fulcrum socket upon the bar $A\ D$ until the pin point F is also upon the straight line, then clamp the socket and take the pin out. The instrument is now set to the proportion 4 to 5, and only requires the fulcrum to be placed in the hole in the weight, after this has been placed in position on the drawing board. Settings for other indicated proportions obtained in the same way.

It will be observed that this method of "setting" the instrument is exceedingly simple; it has also the further great advantage that the bars of the pantograph are not in any degree strained or bent by the operation, as often happens when the fulcrum is fixed in the weight before setting the arm $A\ T$ and the fulcrum socket. The weight can also be placed in any desired position on the drawing board and the fulcrum afterwards inserted in the hole in the weight.

The setting just obtained gives the proportion of 4 to 5, that is, in Fig. 3, if x or $T\ T^1 = 4$ units, then y or $P\ P^1 = 5$ units. If the reproduction is to be larger than the original, put the pencil in the socket P and the tracer in the socket T, but if a reduction is desired, that is, it the reproduction should be smaller than the original, reverse the points, putting the pencil in the socket T and the tracer in the socket P.

The Settings marked on the bar $A\ T$ are the following:—

Division	5,	Proportion	1 to 1	Division	35,	Proportion	1 to 2
"	11,	"	9 " 10	"	41,	"	2 " 5
"	15,	"	5 " 6	"	45,	"	1 " 3
"	17,	"	4 " 5	"	50,	"	1 " 4
"	20,	"	3 " 4	"	53,	"	1 " 5
"	25,	"	2 " 3	"	55,	"	1 " 6
"	29,	"	3 " 5				

To find "Settings" other than those indicated on the bar A T.

The bar $A\ T$ is divided into 60 equal parts, zero being at A and 60 at T. Settings are obtained by means of the following formula,—

$$\text{Setting} = 65 - \frac{60 \times x}{y}$$

in which x = the movement of the point from T to T^1,

and y = the movement of the point from P to P^1.

Example:—Find the Setting for the proportion 5 *to* 9.

$$\text{Setting} = 65 - \frac{60 \times 5}{9} = 31.7$$

The lower end-edge of the bar $A\ B$ must therefore be put in contact with the division 31 plus $^7/_{10}$ths of a division on the bar $A\ T$, after which the fulcrum socket is set in the manner described.

This Pantograph may also be used for the reproduction of drawings so that the *area* of the copy may bear a given proportion to the *area* of the original. The settings used for this purpose are obtained by the following formula:—

$$\text{Setting} = 65 - \frac{60 \times \sqrt{x}}{\sqrt{y}}$$

Thus, if we wish to reproduce the plan of a certain plot, or the drawing of a piece of machinery, so that the area of the original shall be to the area of the copy in the proportion of 4 to 9, we have

$$\text{Setting} = 65 - \frac{60 \times \sqrt{4}}{\sqrt{9}} = 25$$

An arrangement is provided for lifting the pencil from the surface of the paper, so that any portions of the original may be passed over by the tracer, without showing corresponding marks on the reproduction.

The instrument is substantial and carefully made, and will, we are sure, give satisfaction to all those who are in want of a good Pantograph at a moderate price.

The probable error of the mean of all the angle readings

$$= \pm\ 0.67 \sqrt{\frac{1\ 20}{20}}$$

$$= \pm\ 0.67 \sqrt{0.06} = \pm\ 0'.164$$

which makes our final result, or the direct distance from the transit to the targets 828 73 feet $\pm$ 0.375 foot, being a probable error of 1 in 2200, which is very small for a distance of over 800 feet.

We have received from a subscriber the following communication:—

"I have read with the greatest interest your article on "A New Telemeter Target" in the June number of THE COMPASS. It is certainly a great stride in the direction of practical Telemetry, and for the measurement of hectara mining claims in the rough mountains of Mexico far surpasses anything of which I have knowledge. Engineers or surveyors doing this class of work are, in most cases, poorly paid—the majority of mine locators are so poor—and any method that expedites the work without sacrificing accuracy is a desideratum, a want fully met for the first time by your new Telemeter Target. The price seems to be high, but I have no doubt is as low as Messrs. Keuffel & Esser Co's high grade of work will allow.

I do not quite see the necessity for formulas (4) and (5). Is not the true horizontal distance $O\ C$* obtained directly in all cases whether on level or sloping ground? The horizontal angle $A\ O\ B$ is always the measured angle and $A^1\ C^1 = A\ C$ is always known, and from the solution of $O\ C\ A$ the horizontal distance $O\ C$ is found. In the vertical triangle $O\ C\ C^1$, $O\ C$ has been found and the vertical angle measured and therefore $C^1\ C$ results from the formula

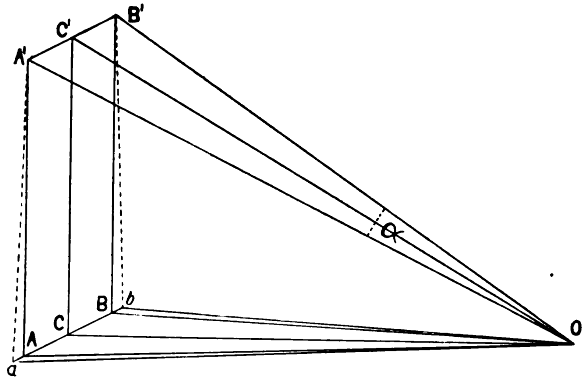
$$C^1\ C = O\ C \text{ tan vertical angle.}$$

If the inclined distance is wanted for any purpose, it may be obtained as is well known, from the formula

$$C^1\ O = \frac{C\ O}{\text{Cos vertical angle}}.$$

We have received a similar letter from another reader. While respecting the opinions of our friends, we are unable to accept, in this case, their corrections, and that for the following reasons.

* We have not reproduced either of our friends' figures, but made our own apply to their arguments. We ought to state, however, that they do not show the slanting lines A^1a and B^1b, upon which in reality the contention depends.



Let in the above figure $A^1\ B^1$ represent a Telemeter Target, placed on a hillside, the distance between centres being 4 feet, and O be the position of an observer in the valley below, and let

$O\ C$ = 400 feet = horizontal distance,

$C^1\ C$ = 300 feet = vertical height, then

$O C^1$ = Direct Distance.

$$= \sqrt{\overline{O\ C^2} + \overline{C^1\ C^2}} = 500 \text{ feet.}$$

It will be evident that

$$C^1\ O = A^1\ C^1 \times \text{Cot } \tfrac{1}{2}\ \alpha$$

whence $$\text{Cot } \tfrac{1}{2}\ \alpha = \frac{C^1\ O}{A^1 C^1} = \frac{500}{2}$$

$$= 250 = \text{say } 14'$$

whence $$\alpha = 28 \text{ Minutes.}$$

Now as the angle α measured on the horizontal limb of the transit is equal to the horizontally projected angle $A\ O\ B$, we have also

$$C\ O = A\ C \times \text{Cot } \tfrac{1}{2}\ A.O\ B,$$

whence, $C\ O$ being = 400 feet,

$$A\ C = \frac{C\ O}{\text{Cot } \frac{1}{2}\ A\ O\ B} = \frac{400}{\text{Cot } 14'}$$

$$= \frac{400}{250} = 1.6 \text{ feet,}$$

whence $A\ B$ = 3.2 feet.

If, however, as argued by our correspondents, this new telemeter target gave in all cases "*true horizontal* distances whether it be on the same level as the transit or not," we should have $A\ B$ = 4 feet and not 3.2 feet.

It is, therefore, clear that the elevated chord A^1 B^1, subtended by the angle α, is not the same length as the horizontal chord A B subtended by the angle A O B which is equal to α. The angle at O subtended by a horizontal chord a b of 4 feet, at 400 feet distance, would be $\frac{400}{2} = 200$ $=$ Cot 17′. whence the angle a O b would be 34′ instead of 28′ as the angles α and A O B.

Again suppose the vertical height C^1 C were 400 feet, then the angle α would be smaller, or about 12′ and if C^1 C were 500 feet, the angle α would be still smaller, or about 10′. It is, therefore, impossible that the three different measurements of α, that is 10′, 12′ and 14′, should all give the same horizontal distance C O of 400 feet, which would be the case if we allowed that the "true horizontal distance C O is obtained directly by the measured angle α in all cases whether on level or sloping ground." True, if the vertical angle C O C^1 is *very* small (less than 2°), the difference between the direct or inclined distance and the horizontal distance is inappreciable and may be neglected, but in mountainous districts, such as those referred to by our correspondent, this is very frequently not the case, and then it is absolutely necessary that the correction be made, as given in our formula (4), — which stands thus

$$\text{Horizontal Distance in Feet} = 11278.56 \times \frac{n}{m} \times \text{Cos } a,$$

a being the angle of elevation or depression of the transit telescope, which in our figure is 36° 52′, whose cosine is 0.8, which gives us 500 $\times$ 0.8 $=$ 400 feet $=$ C O.

Again:—If two chords of an arc are of equal length, and their respective radii vary in length, then the apex angles subtended by these chords must and will be of different magnitudes, and if the apex angles are equal, and their respective radii vary in length, then the chords must and will be of different lengths.

If, therefore, in two measurements, as A^1 O B^1 and a O b, one of the three quantities, chords, radii or apex angles, differs in one case from the same quantity in the other case, then one at least of the other quantities must also proportionately vary; that is, *one* quantity cannot vary and the other two be alike, or if two quantities *are* alike, then the third ones will also be alike.

As, therefore, the chords A^1 B^1 and A B subtended by the angle α are of different lengths, then the radii, and consequently the direct and horizontal distances C^1 O and C O must be of different lengths.

We should be glad to have the opinion of any other of our readers on this subject.

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CORRESPONDENCE **should be addressed to the Editor of THE COMPASS, 127 Fulton Street, New York City.**

All such bearing upon the topics to which the Journal is devoted, will be thankfully received and acknowledged with pleasure.

CONTENTS.

STEEL TAPES WITH TEMPERATURE COMPENSATING SCALE.

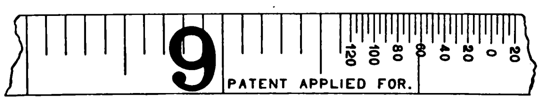


Fig. 1.

IT IS LITTLE conceived by some what importance should be attached to the question of temperature when making careful and would-be accurate measurements with a steel tape or chain. That steel expands when under the influence of heat is known to all, but it is generally supposed that the rate of expansion is so slight, that it can hardly affect the results of measurements in the field, and may safely be ignored.

The Coefficient of Expansion of steel is not an absolutely fixed quantity, as it varies from 0.0000055 to 0.0000070. For steel tapes it may be taken, however, as being pretty uniformly 0.000006 for each degree Fahren-

heit, expanding with heat and contracting with cold, that is, if a tape could be made which would measure exactly 1000000 inches in length when its temperature is 62° Fahr., it would if the temperature were 63° be 6 inches longer, and if the temperature were only 61°, it would be 6 inches shorter. Sixty-two degrees Fahrenheit is the temperature called "standard" by the office of Weights and Measures of the U. S. Coast & Geodetic Survey, and comparisons of steel measures are made at this temperature.

If, therefore, we have a steel tape, 100 feet long, which is standard, that is, which really measures 100 feet at 62° Fahr., and suppose this tape were being used when its temperature was reduced 50 degrees to 12°, then the tape would in reality measure $100-(0.000006 \times 50° \times 100 \text{ ft.}) = 99.97$ feet. Measures taken with it would, therefore, be cumulatively erroneous to the extent of one in 3333, (which for a mile would make a total error of 1.584 feet) and would have to be subjected to a temperature correction if anything like precision were required.

As a difference of temperature of 50 degrees and more in the short space of a month or even less, is no uncommon thing in this country where differences of 30 degrees between two consecutive days are far from rare, it will be seen that this factor of expansion should not be ignored.

Figure 1 represents the last 2 inches of a new 100 foot steel tape, $\frac{1}{2}$ inch wide, fully divided into tenths and hundredths, by means of which the correction for temperature may be made while a measurement is being taken, subsequent calculations becoming thus unnessary. The large figure **9** determines the division $99\frac{9}{10}$ feet; to the right of this are seen 6 subdivisions of $\frac{1}{100}$ foot each, then follows a short but finely graduated scale from 120 down to 0 and on to — 20. This is a thermometric scale, made in accordance with the coefficient of expansion 0.000006 for each degree Fahr., and based upon 100 feet, the total length of the tape, thus making 0.0006 for one degree, or 0.06 feet for 100 degrees. The 100 foot figures are placed at 62° of this scale, a short line on the lower edge of the tape indicating exactly its position. If the temperature of the tape when being used were 80° F., then, since the tape will have expanded by reason of the additional heat, the 100 foot length division will be in reality at 80 of the small scale; while if the temperature of the tape were reduced to 40° F., as the tape will have contracted, the 100 foot length division will be in reality at 40 of the small scale. By this means the correction for temperature is made without the application of the usual formula, each measurement of 100 feet being thus precisely one hundred feet.

If it be required to measure a shorter length than 100 feet, then the correction must be made by means of the formula, thus for a length of 80 feet and a temperature of say 92° F., we have

$$80 + (0.000006 \times 30° \times 80 \text{ ft.}) = 80.0144 \text{ feet.}$$

As the temperature is higher than the standard the tape has expanded, so if we wish to *take off* the measurement of the 80 feet division, it will in reality be 80.0144 feet, but if we wish to *set off* 80 feet exact, then we must use the division 80 — 0.0144 = 79.9856 feet, reading off by the actual graduations of the tape 79.98 feet, and estimating as nearly as possible the position of the additional 0.0056 feet.

That the question of expansion is worthy of consideration will be evident from the following suppositionary case, which may not infrequently be met with in actual practice. Suppose a measurement of 1000 feet has been made on a given day with a temperature of 50° F., and that for some reason or other it is necessary to verify it on the morrow, when the temperature has risen to 70°, and that the factor of expansion has not been taken into account; the difference between the two measurements would be

$$0.000006 \times 20^\circ \times 1000 \text{ ft.} = 0.12 \text{ feet},$$

so that clearly they could never be made to agree.

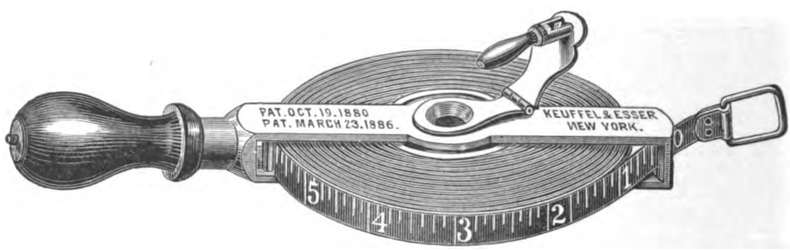


Fig. 2.

We can strongly recommend these steel tapes, which are of the Excelsior brand shown in Figs. 2 and 3, as they are made to U. S. Standard at 62° F. and are consequently thoroughly reliable.

Figure 2 represents what is styled a Stevens Excelsior Steel Tape, ½ inch wide, on a Patent Brass Frame, with Patent folding Handle, while Fig. 3 is a Columbia Excelsior Steel Tape, ½ inch wide, in bent leather

Fig. 3.

case with Patent folding flush handle. They may be had divided in feet

and inches or in feet and tenths as desired, the graduations in all cases being clear and distinct.

In what precedes we have naturally assumed that a uniform rate of tension would always be applied to the tape; this should in the case of the STEVENS and the COLUMBIA be from 6 to 7 lbs. for 100 feet, with a proportionate amount for shorter lengths.

ADJUSTING AN ENGINEER'S LEVEL.

We have received from a correspondent the following communication which we publish with pleasure, hoping it may interest some of our readers.

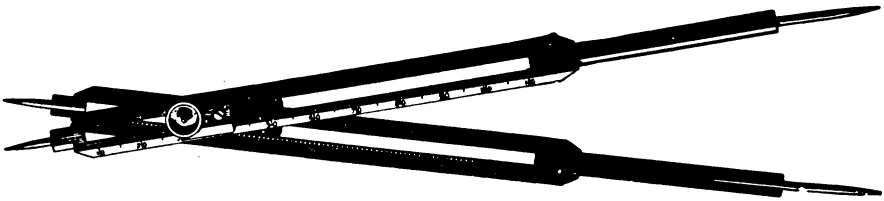
"Below I give you a method of adjusting an Engineer's Level which I have never seen in print although I consider it far superior to that set forth in the books. The method is not original with me and I do not know the author.

The first adjustment, set forth in all the books on this subject, consists in getting the intersection of the cross-hairs in the centre of the telescope. This is done by clamping the instrument, sighting to some distant point, and moving the cross-hairs until they cover the point in all positions when the telescope is rotated in the wyes.

The second adjustment, which is the one I wish to speak more particularly of, is generally performed by bringing the bubble into the centre of the tube, then lifting the telescope out of the wyes and reversing it end for end, and if the bubble does not return to the centre, bringing it half-way with the adjusting pin and the other half with the leveling screws. This is repeated until the bubble remains in the centre when either end of the telescope is in front.

The superior plan is as follows:—After the cross-hairs are adjusted to centre of telescope, go out on a level piece of ground and set up the level near its centre. Have the rodman step off equal front and back sights, say about 500 feet each, (or rather have them accurately measured) and drive a peg at each station. Take a reading upon a rod held on each peg, when the difference of the readings will be the true difference of level of the pegs, no matter how much out of adjustment the level may be. Then go near one peg, set up the level and take a reading on the rod on the near peg. Calculate what the reading should be on a rod held on the distant peg, and have the target set to that point. Then with the leveling screws bring the telescope to make the cross wires cut the target, after which bring the bubble to centre of tube by means of the adjusting pin. Repeat the process if necessary. The superiority of this method is evident."

UNIVERSAL PROPORTIONAL DIVIDERS.



Having been informed recently by Dr. Coleman Sellers, of Philadelphia, that proportional dividers had been constructed many years ago with a fully and equally divided scale from point to point, we determined to investigate the matter, and with this object in view at once went to Philadelphia, where, we were informed, full particulars might be obtained. We directed our steps to the Franklin Institute, access to its valuable library being allowed us by Dr. Wahl's kind permission.

Our researches resulted in the discovery that an engineer named Oliver Byrne invented a proportional divider, fully and equally divided from point to point, these divisions being further subdivided by means of four verniers, and that the first instrument of the kind was made by Cary, of 181 The Strand, London, and was exhibited and explained at York, before the British Association in the year 1844. A full description of this interesting instrument, which the inventor termed a "Byrnegraph" is given in "A Dictionary of Machines, Mechanics, Engine-Work and Engineering," edited by Oliver Byrne, and published by D. Appleton & Co., New York, in 1850. It is remarkable that the description of the Byrnegraph was expunged from later and enlarged editions of the Dictionary, whence we gather either that the instrument did not in those days meet a felt want, or that its cruder construction prevented the value of the principles involved being made of practical use.

As a natural result of this discovery, we immediately gave instructions to have our application for a patent withdrawn. This does not, however, imply that the Universal Proportional Dividers (fully described in The Compass, for September, 1892), will be withdrawn from sale. On the contrary, the substantial appreciation accorded them will encourage us to make their value more widely known. We also understand that as a testimony to their usefulness, similar instruments will now be put on the market by others, so all we can do is to claim for our invention independent discovery, (we are debarred by the regulations of the Patent Office from obtaining protection for the same), which merit cannot be claimed on behalf of any makes other than the Paragon. This original brand will be known by the registered name "Universal" Proportional Dividers.

Our thanks are due and are hereby publicly tendered to Dr. Coleman Sellers for his kindness in bringing this matter to our notice.

We conclude these remarks, which in justice to ourselves we felt it right to make, by bringing before our readers Dr. Seller's appreciation of this re-invention. He wrote us as follows under date October 25th, 1892:

"Having for some days used your new arrangement of proportional dividers, made by Keuffel & Esser Co., and described in the "COMPASS," Vol. II. page 47, I find the method of division by one scale and a Vernier, accompanied by the table of settings for various ratios, is very much more convenient than the ordinary graduations of the instrument, where it is graduated in several different places, for lines, for circles and for solids and planes, as less time is taken to make the setting with the new instrument than with the old one, and its scope of utility is much increased, making it in every way preferable for engineer's use.

"I thank you for having called my attention to this instrument and although provided with very excellent proportional dividers of the old style, I find this so much more convenient as to confirm me in its use in preference to the other."

A NEW PIVOT JOINT FOR DIVIDERS AND COMPASSES.

THE VALUE and usefulness of dividers and compasses depends mainly upon two points, namely, material and workmanship, the latter being especially important in the joint, which being the most essential part of the instrument, requires the greatest care to make it perfect.

Numerous devices have been brought out with a view to the production of correctly constructed divider joints, but very few of them have proved satisfactory, and of these the "Pivot joint" has been considered (by all those who have no objections to a handle on the larger sized compasses) the one whose construction is the most perfect.

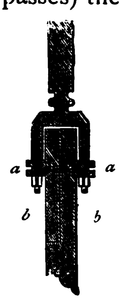


Fig. 1.

Fig. 1 shows this joint as it has generally been made. The two pivots *a, a*, which pass through the arms of the fork, not only hold the heads of the two divider legs in their respective places, but when screwed against the heads produce the desired friction, after which they are secured by the small set screws *b, b*. This mode of preventing the pivots from becoming loose has great objections, seeing that the set screws spoil the thread of the pivots, (thus destroying the means of readjustment), and being naturally very thin and slender, bend or break easily, and on account of their position col-

lect dust and dirt, thus impairing the delicate working parts of the joint; the entire combination of the joint is also very unsightly.

In order not only to preserve all the good features of this style of joint, but rather to increase them, Mr. Herman Esser, of the firm Keuffel & Esser Co. has devised an improved mode of absolutely locking the pivots, which, without doubt, adds to the appearance and durability of the joint. The essential features of this new pivot-joint, *applied solely* to PARAGON *instruments*, as shown in Fig. 2, are the following:

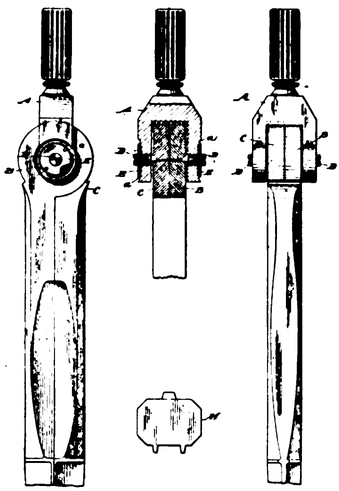


Fig. 2.

The pivots *D*, *D* are held securely by means of thin steel discs or lock-nuts *E*, *E*, which fit nicely in circular recesses in the arms of the fork, and which are tapped to correspond with the screw threads of the pivots. Each disc is provided with two notches *e*, *e*, adapted to receive the prongs of the key *M*, by which it is turned round. After the screws or pivots are set to give the desired amount of friction to the heads of the divider legs *B* and *C*, the disc is screwed up, causing it to press strongly against the base of its recess, thus holding the pivot firmly in its place. By the sinking of the thin lock-nuts in the recesses as shown, the instrument presents a tasty, well-proportioned and ornamental appearance, while all risk of injuring the screw threads of the pivots or of breaking set screws is avoided, and no place for collecting dirt exists.

The new series of PARAGON dividers and compasses with pivot-joints, now presented, will certainly tend to make this class of instruments more popular, especially as it is one which we can recommend as confidently as we have already done PARAGON dividers with tongue-joints, and other instruments of the same brand.

TO TRISECT AN ANGLE.

THIS GEOMETRICAL problem which has puzzled so many mathematicians and others, has been solved by Mr. O. M. Tennison, of New Orleans, in a very ingenious manner. The solution sent by him to the *Times-Democrat* of that city is so simple that we wonder it was not discovered before; it is as follows:—

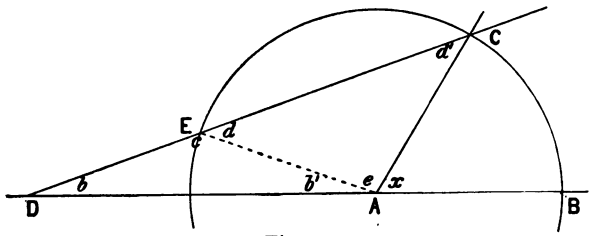


Fig. 1.

Let $A\ B$ and $A\ C$ in the above figure be two straight lines forming the given angle x, whose third part it is desired to find by geometrical construction.

Extend the line $A\ B$ indefinitely, and on it describe a semicircle $E\ C\ B$ of any convenient radius $A\ B$, having its centre at A.

On any convenient straight edge, as that of a ruler or a strip of paper lay off a distance equal to the radius $A\ B$ of the circle; apply this straight edge to the figure in such manner that it may cut the circle in E and C, and meet the straight line $D\ B$ at D, the distance $D\ E$ being that laid off on the straight edge equal to the radius $A\ B$, then draw the line $D\ C$ and the radius $A\ E$.

Now by construction $A\ D\ E$ and $A\ C\ E$ are isosceles triangles, having the angles b and b^1 of the one, and the angles d and d^1 of the other, respectively equal to each other, then

$$\text{Angle } c = 180° - b - b^1 = 180° - 2\,b;$$
$$\text{"} \quad d = b + b^1 = 2\,b;$$
$$\text{"} \quad e = 180° - d - d^1 = 180° - 2d$$
$$= 180° - 4\,b,$$

therefore $\qquad$ angles $x + b^1 = 4\,b,$

whence $\qquad$ angle $x = 3\,b,$

$\qquad$ " $\quad b = \frac{1}{3}\,x,$

and $\qquad$ " $\quad d = \frac{2}{3}\,x.$

THE METRIC SYSTEM.

We have received the following communication from the Secretary of the New Decimal Association (established to promote the adoption of a Decimal System of Weights, Measures and Coinage in the United Kingdom), dated, London, 8th May, 1893:—

Messrs. Willans & Robinson, of Thames Ditton, Surrey, have now adopted the metric measures in their works. They have adopted this course owing to the practical convenience of the Metric System, and to

their conviction that they thus obtain commercial advantages in securing orders in those countries where the metric system is in force, and in order that parts of engines made by them may be interchangeable with those made by their licensees abroad. We are authorized to state that their existing standard sizes of engines, chiefly used for non-condensing purposes, will remain unaltered, in order, among other reasons, to avoid inconvenience to present users of their engines, the gauges, templets, etc., only, for the sake of uniformity in the works, being stamped to the nearest hundredth of a millimetre. A new series of engines, however, specially designed for condensing work, which is now in hand, and all new works will be constructed to even measurements on the Metric System.

Mr. Charles Louis Hett, of the Turbine Foundry, Brigg, contemplates adopting this system of measurement in his Works also."

Messrs. Jno. Birch & Co., of Queen-street-place, London, have recently sent to London *Engineering*, the following letter received from an English engineer in Brazil, which goes far to prove the statements which appeared in our May issue.

"I may tell you that foreign manufactured goods of all kinds are pushing us out of the market here, and this is greatly due to the fact that foreign manufacturers send out their catalogues made out in the language of the country, and all weights and measures in the metrical system. Engineers here will not take the trouble to convert our hodge-podge mixture of weights and measures into the metrical system, and indeed, it is not to be wondered at; they consequently do not understand them, nor have they any basis for comparison with the prices, strength of cross-section, etc, of Belgian and French goods which are in favor here. I assure you I have known Brazilian engineers say to me, 'We like your English goods very much. We believe them to be the best, and probably the cheapest in the long run; but we do not understand your weights and measures. They convey nothing to our minds, and we, therefore, find it impossible to estimate from them.' "

THEODOLITES.

THE FOLLOWING suggestion offered by "Toothed Wheel," appears in a recent number of *Indian Engineering.*

"The expense of theodolites appears to be due to the accuracy of parts in their construction, necessitated by the readings being taken directly from the scale of degrees. The introduction of mechanism like a watch would enable a theodolite telescope when turned through a certain angle to indicate that angle in degrees, minutes and seconds by hands moving on a dial with perfect accuracy—the only inaccuracy arising from a *play* between the teeth of the wheels used—which can be eliminated."